SUSTAINABLE REFURBISHMENT OF ITALIAN BUILT HERITAGE: RESEARCH AND EDUCATION GOALS AND METHODS

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Summary
The paper regards an educational activity carried on in two Italian universities (Engineering Faculty of Pavia and Architecture Faculty of Genoa). Specific items of the work are: sustainable design criteria, energy saving, energy consumption monitoring and refurbishment strategies for Italian built heritage. Monitoring and metering energy consumption is quite easy to carry out for public, commercial and office buildings. Determination of energy consumption of residential buildings is more difficult. A deeper consciousness about the energy consumption in every-day life and the consequent pollution is one of the aims of the European Directive 2002/91/EC on the energy performance of buildings, where Article 12 indicates that “Member States may take the necessary measures to inform the users of buildings as to the different methods and practices that serve to enhance energy performance”. In this way the authors are working carrying on didactic training at different levels (university courses, PhD thesis and professional training courses) focused to make students feel responsible of the environmental problem and, for some levels, to give them the instruments to choose the best refurbishment strategy to increase energy performance of the restoring building.

1. The general frame

1.1 Health, waste and energy consumption in Europe

About 80% of European citizens lives in urban areas, where the effects of environmental problems are more intensively perceived. Noise, air pollution, vehicular traffic, lacking in maintenance of built environment, bad environmental management and scarce strategic planning aid the raising of health problems and make worse the quality of life. An increasing number of urban areas present these symptoms of excessive tension; urban pollution, in fact, is the most frequent joined mental image to the concept of “environment”.

To solve many problems of health due to particular environmental situations in Europe, it is necessary to radically improve the quality of life and the urban environment. The planning of high level of environmental protection is one of the fundamental presuppositions to ensure a sustainable urban development. Moreover, the quality of built environment has a strong influence on the quality of urban future assessment.

The heating system and the artificial lighting of buildings absorb the main part of energy consumption (42% in total, 70% for heating) and produce 35% of total greenhouse gas emission. The buildings and the built environment produce, per year, 450 millions of tons of waste materials from demolition (more than a quarter of the total waste produced in all the activities). Moreover, European citizens pass more than 90% of their time inside the buildings: a bad design or a wrong use of building methods and materials could have a significant effect on the health of their occupants and could make extremely expensive the maintenance, the heating and cooling, with a strong repercussions on elder and poorer people.

For all these reasons, renovated methods in building design, construction and refurbishment could allow a notable improvement of environmental performances of the cities and of the quality of life of citizens.

1.2 Sustainable refurbishment

Following this point of view urban renewal and building refurbishment represent an immediate sustainable
action. In Italy above 3 million of dwellings (almost 12% of total amount) need radical interventions to solve situations of decay, pollution and energy consumption. Sustainable refurbishment of housing could represent an unique occasion, as remarked in an important communication of European Commission. Building refurbishment is, in a fact, a crucial step toward the achievement of urban landscape environmentally and socially sustainable.

A huge challenge for the future passes through the refurbishment of existing buildings, especially erected in the second part of 20th century, following sustainable principles and criteria. The best way to respect the obligations assumed with Kyoto agreement is, in fact, the improvement of energy performance of residential buildings. For example, the adaptation of the old and recent real estate property through its thermal insulation could reduce CO2 emission in the atmosphere and energetic charge of 42-46%.

Practically, refurbishment is more complex than a new construction, because different situations require particular and sometimes complex solutions. Anyway, sustainable refurbishment presents notable environmental benefits compared with demolition and re-construction, as it does not require energy to produce new materials.

Moreover, the attention to existing real estate property will become particularly important after the adhesion of the new member countries. In the post-second world war period in Europe millions of housing have been built, due to the increase in population, the migration to big cities and the destruction of the war. Nowadays more than 40% of the inhabitants of the major cities of these countries live in huge pre-built complexes (in Bucharest the percentage grows up to 18%). These settlements, built in the second part of last century, represent a challenge for urban sustainability, both for their enormous dimensions and for lacking of maintenance and energy efficiency. Despite data are still incomplete, around a fifth of apartments need light maintenance, three-fifth need heavy refurbishment and a fifth should be completely demolished and constructed again [1].

More or less the same happens in Italy, especially in the big cities grown-up in the fifties and sixties with the industrial progress of the country, and, moreover, especially in the peripheral areas. Post war residential building stock, all around Italy, is now characterised by a state of obsolescence and a lack of performances that demand a very urgent intervention. Maintenance and refurbishment represent, therefore, one of the main significant building sectors. Research and studies supporting refurbishment actions from the technical point of view mainly concern the “durability” of the buildings, that is the quality of materials and components and their duration (or life span). Nevertheless, other significance indicators, even if just technical, must be taken into consideration. Other requirements have nowadays to be taken into account to program upgrading and refurbishment, besides the duration and the stability of the building, the safety, the functionality, the aesthetic appearance: sustainability, hygrometric comfort, energy saving and consumption reduction, indoor air quality, lighting and visual comfort, health, integration with natural environment. Especially in the last few years, moreover, the principle of sustainability and re-naturalization has lead many refurbishment processes to also reduce pollution and consumption, to use renewable sources instead of the traditional ones and to increase healthy conditions inside housing units. The philosophy, in these cases, was to build inside the environment and landscape not against them.

Sustainable construction of new buildings and infrastructures and sustainable refurbishment of existing buildings could lead, within the half of 21st century, to a sensible improvement of environmental performances of European cities and of the quality of life of their inhabitants. Against these considerations national policies towards the problem or urban and building renewal are under modification (expressed, for example, in the last Italian financial law that previews economical benefits for maintenance and refurbishment operations aimed to the increase of energy performance of the building or dwellings).

2. Education goals and methods: data collection on energy performance of residential buildings

2.1 Behavioral guidelines

Working in the education field, although at the last level (university), the first step that could be undertaken by the teachers corresponds to making people - and students - aware of the huge environmental actual and future problems linked also to the building sector. This goal could be pursued using traditional methods (lessons, seminars, courses…) or even involving the students themselves in a more effective way.

The direct involvement of the student (making him working on it’s own house) responds to the major purpose of each kind of teaching, that should be the raising of attention in respect to several problems and, in general, the progress in culture.

Recent studies on the huge field of norms and regulations and their application on the technical field (for example the building sector) demonstrate that “behavioral” norms (intended as a complex of advices) is often more incisive than imposition. This aspect has effects both on the education structure of the courses and on the technical language of publications and works, often expressed in terms of “guidelines”. The form embedded in the guideline, in fact, suggests a trace to be passed, indicates a process to be pursued and not,
necessarily, a set of fixed solutions to be applied. This kind of attitude, that directs also the practical experimentation below described, leads the student to:

- the knowledge of problems,
- the correct setting of a technical project
- the responsible choice of the final technical solution, that is never fixed and unique, but could be different from case to case.

The involvement of the student on its own house opens to margins of responsibility, implies somehow the individual engagement and aims to give a problematic dimension to principles and decisions. Instead of making the student work on case studies given by the teaching, they have to work, as training filed, on their own home/apartment/house. Main idea is to make the students responsible for the data collection regarding the actual state of the building (technical features and energy consumption) in order to make him touch directly the environmental and energy problem (consumption and saving).

The first step of the work has been the construction of an excel sheet to collect information and to construct a huge data base on technical features and energy consumption of the residential building where the students live. This approach can contribute to the diffusion of the personal interest on the energy saving problem. The student perception of the problem can be activated not only by the comparison of his own data with conventional ones but mostly with the confrontation among the various collected data. Comparing energy consumption of the same building typology and finding that his values are higher than the others, can stimulate the wish to reduce them by identifying the best possible solution.

2.2 Energy performance of one’s own house – Data collection

The file, in an excel format, is divided into 9 sections and is contained in a A4 sheet format. The student has the duty to collect the data required and to fill in the sheet.

The first section regards the image and shape of the building: small drawings and pictures represent the main façade of the building, the localization in urban, sub-urban or peripheral context and the schematic plan of a floor type (with the orientation and general dimensions). If possible, it is important to enclose the elevation of the building in its full extent.

The second section contains all the technical features general requested to use software programs (or even to proceed with manual calculations) and is named “Building features”. This section contains lines for the location of the building (province and municipality); age of construction (year); residential typology; number of floors; height of the building and of the floor; gross volume heated; total external opaque surfaces (A); glazing surfaces (B); ratio B/(A+B); net surface per floor and per apartment; medium number of occupant per floor; useful surface of covering/roof plane o pitched.

The third section regards the features of heating system: the student has to indicate if the system is centralized or not; if there is an individual consumption accounting; type of radiators; type of technical system, of boiler and year of installation; type of fuel; the power and performance of the boiler and the period of heating.

The fourth section concerns the technical features of external walls and their thermal behavior: materials, layers and thickness of external walls, floors, pavements, windows and U values for each of the components and, moreover, contains the control of interstitial drew-point.

The fifth section regards the consumption monitoring of a reference year: electric consumption, heating fuel consumption, electric consumption for common spaces, global fuel consumption, specific heat, water consumption.

The sixth section contains the attribution of the building to the energetic class. This step corresponds to the calculation of the energetic demand of the building envelope (external walls, floors and roof) and of technical installations using, as an example, the procedure set up by the province of Bolzano and very well known in Italy as “casa-clima experience”. Using a user-friendly and free access software, it is possible to recognize the class of the building. Energetic classes are divide into 8 ones and colored from blue/green (for the passive house) to the red (the worst energetic and consumption class). This passage of the experimentation can be impressive for the students, because looking at the color of their building they could immediately appreciate the real state of the building and the impact on consumptions.

The seventh section regards the evaluation of the application of a solar thermal system. Necessary data to fill the sheet are: useful surface of roof; other useful surfaces; percentage of heating requirement; typology of solar panels and technical features; solar radiation; produced energy.

The eighth section regards the actions to perform to reduce energy consumption with different technical operations: improving thermal performance of opaque surfaces through insulation; improving energy performance of glazed surfaces through substitution of windows; insertion of solar screen; intervention on the boiler; intervention on the hydraulic circuit. Part or all these interventions could improve the “energy class of the building”.
2.3 Energy performance of one’s own house – Data elaboration

The first and second sections can be used to order data sheets depending on a building classification that can take into account shape, height, number of floors and of apartments, age of construction.

The 3°, 4°, 5° sections allow collecting a significant amount of data on the electric and thermal consumption referred to a reference year. The results can be evaluated one by one and also globally by comparing with plots that represent the energy consumption by inhabitant (electric) or by volume (thermal).

This method allows each student to approach the energy saving problem also with the comparison among data of his colleagues’ houses.

Often the reference data on the consumption reasonable levels don’t take into account the building characteristics and are determined for some common building typologies (large buildings rather than little single family houses). The possibility of comparison among buildings with the same characteristics can aid a more adequate data evaluation.

The sixth section represents a slightly more complex operation, as the student must utilise software performed for technicians, expert in building energy performance, to obtain the classification of his house.

This procedure is completely developed by each student that, in the development of the course lessons has studied the principles of heat transmission, their applications on building walls, heat transmission in heat exchangers and also some outlines on heating systems in buildings.

The lessons programs differentiate among the various courses of the different Engineering Degrees (Civil, Electrical, Mechanical, Environmental, Building Engineering or Architecture) but there is a common matrix that allows to guarantee a basic common knowledge on Thermodynamics and Heat transmission. This permits to students to handle the most part of the data sheet and to obtain at least the building energy classification.

The availability of evaluation software becomes every day wider. At present almost two or three software are employable for this aim. They have some different characteristics, as they present simplifications to make the calculations easier, mostly for existent buildings, where some information are difficult to obtain.

This operation must be explained very carefully to the students, as the input data must be adequate to evaluate in the most accurate way the building energy performance.

From this section the energy consumption class of the building can be calculated. The student can become aware of the annual use of energy resources for the building consumption management.

The comparison among energy consumption levels of each examined building and which kind of action could be realized to obtain better results will be developed in a concluding seminar. This one will take place at the end of courses to inform the students about the investigation.

Part of the students can apply their knowledge to the solar thermal system dimensioning, filling out the seventh section of the scheme.

The required characteristics allow an approximate evaluation of the panels' surface fixing the thermal needs. The student can balance the available surface of his roof with the warm water needs of the house or also can estimate to cover heating needs partially.

The results can be verified with the software already used in the previous section to evaluate the improvement of the energy saving. The same procedure can be applied to verify the efficacy of other solutions aimed to the energy consumption reduction (increasing insulation, changing windows, reducing uncontrolled ventilation, etc).

2.4 Energy performance of one's own house – Observations

A first approach to this data collection was performed starting from October 2006, on the basis of 17 students’ work in the course of Environmental Applied Physics that deals with advanced heat transfer problems, energy saving techniques, environmental quality and also with the solar energy utilization for water heating. The course is attended in the first year of the Master degree in Environmental Engineering. Therefore students have already done the basic course in Applied Physics of the Three Year Degree.

The results have been encouraging as the work was developed mostly independently, with the desire to discover something interesting on the capabilities of the dedicated lessons to apply in practice. The results were obtained without high difficulties, probably understanding the utility of the collected information.

A second step was performed in the courses of Applied Physics dedicated to students of the second year of the Three Year Degree. The amount of data was wider as all the courses were involved and as the application was considered a compulsory drill for the final examination.

As expected, the results appear to be less significant than the others, as the students are younger and the aim of the work was less understood, probably due to the higher interest to reach a good result in the final examination rather than achieving useful knowledge for the all-days’ life and for the future.
The collection of data encountered some problems due to the following items:

- Availability of the building plan for the older buildings
- Composition of the external walls
- Layout of the heating system pipes

Moreover the reports regarding the electric energy consumption and the gas volume utilized are frequently not retained. Only the payment receipts are often available. Recovering these data is not so easy, as the electric energy consumption is calculated on the basis of different unitary costs depending on the range of consumption and the gas costs vary depending on the energy market.

Another submission of the same scheme, by paper and not by file, was made in the courses of the Third Age University of the Architecture Faculty in Genoa to quite one hundred “older” students. The presentation of the problem was largely appreciated as some of them were interested in restoration of their own home or in minor actions to reach better performances of the house energy management. The collection of data was not too successful even if greater success was expected.

3. Results

The presentation of the collected data must be done with high accuracy to reach the maximum interest by the students. Each student has collected data, has elaborated them, even if partially and has obtained some interesting results about the energy consumption classification of his home. The further step must be the comparison of each situation with all the others, the presentation of techniques to reduce energy consumption, understanding the corresponding money saving, and particularly the corresponding reduction of CO₂ emissions that can contribute to influence the climatic changes problems.

As an example, some data on the main actions can regard the following items.

The electric use reduction:

- The best utilization of electric energy with the use of low consumption lights
- The comparison among energy consumption of older domestic appliances and newer ones.
- The energy saving obtained by shutting down stand-by option of the electronic devices

The reduction of thermal energy consumption can be realized acting on the heating system:

- Better control of the internal temperature by means of thermostatic valves
- Better efficiency of boilers, limits and advantages of condensation boilers
- Best solutions for a complete renovation of the building and the heating system
- Recovering thermal energy by the sun with solar panels and integration with the heating system

Considering a deeper restoration of the building, good results can be obtained with:

- Changing windows and window frames
- Increasing insulation thicknesses
- Reducing thermal bridges

The feasibility of each action can be verified with the software evaluation and the corresponding costs analysis. Each student can determine the amount of money that he and his family can economize each year and how many years are needed to recuperate the expenses for the improvements.

A further step could be the analysis of the national government and regional administrations aids and contributions to find the most convenient and less expensive way to operate in another way, by means of communications in seminars, conferences, etc.

4. Conclusions

A lot of work can be done in this field to make the public popolazione aware of the energy consumption problems. The actions that can be developed in the Engineering and Architecture courses can help to form better technicians who can operate following the energy saving principles. The basic knowledge that they achieve can aid to deal with this kind of problems in the right way, with a deeper comprehension of the problems and the evolution of the techniques.

Such approach should be applied also in different domains, with a more heterogeneous audience, by means of informative actions that can be developed by local government agencies.

However the presence of Universities becomes essential, if expert researchers in the field of heat
transmission, mechanical systems (heating, HVAC system, etc), building thermo-physics that can give also practical information and advices are engaged.

This should guarantee a more equilibrate and objective approach in dealing with this kind of problems, as quite all the actions involved in the thermal performance improvement of buildings can move large amounts of money. In fact, every choice must be evaluated to be effective in the particular context: i.e. condensing furnaces are more suitable when a return water temperature is lower than 55°C, otherwise they work even worse than high efficiency furnaces; with small window surfaces their substitution could be more expensive than the heat loss reduction, etc.

**References**
