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The Energy improvement of school buildings: analysis and proposals for action

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Abstract

The objective of this research is to identify a tool of analysis applicable to school buildings that, through simple input information, can make immediate assessment reduction of energy consumption for heating and associated reduction of CO_2emission, as a result of improvements.The definition of a methodology of analysis allows to evaluate preliminarily the energy performance of the whole school building identifying the most problematic buildings and dividing into groups based on the construction and geometry. In the first phaseall buildings have been filed through information obtained from survey and documentation of archives, then two analyses were performed to compare the energy performance of the whole sample.For the initial analysis it was applied a methodology proposed by ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development) and designed specifically for school buildings; in the second analysis it was calculated the energy performance index for winter heating and compared with the appropriate limit value.Subsequently a sample of buildings was well selectedafter splitting the school building into homogeneous groups. The buildings have been translated into a mathematical model of the building system calibrated on actual energy consumption and dynamic conditions were simulated in order to accurately quantify the impact of the various proposed actions.The results of all combinations of intervention, obtained from the latter analysis, have been used to develop a tool that identified the type of building and construction technology in order to estimate the immediate reduction of consumption and the CO_2emitted.The methodology was applied to the school building of the municipality of Castelfranco Veneto, simulating two scenarios: the first plan to interventions under the PAES (Action Plan for Sustainable Energy) for public buildings while the second considers the possibility of performing all the improvements recommended by the instrument in relation to the entire academic heritage of the city.

*Keywords:*School buildings, Saving, Energy, Dynamic simulation, The Covenant of Mayors

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1. Introduction

The energy and environmental issues in recent years have become increasingly important in the world, it's increasingly urgent to cope with the steady increase in energy demand and to reduce emissions of greenhouse gases to a level that will stop the global warming.In 2011 a Communication from the European Commission (COM / 2011/885 Energy Roadmap 2050) has defined a long-term goal, that is to achieve by 2050 a level of decarbonisation of 80% compared to 1990 while ensuring energy security and a competitive economy. Within the Communication, it shows how implementing the reduction path viably in the proposed indications is a fundamental efficiency of the residential and commercial sectors.Local authorities will be fundamental for implementing the needed actions to achieve the goals set for next years, in fact in 2008 it was launched the Covenant of Mayors [2], a European Commission initiative that commits countries to reducing emissions 20% by 2020 compared to a base year chosen freely.The building industry [4][7] is a key sector in which municipalities may take action, with particular attention to public buildings placed under the direct control of the local authority, for which it would be appropriate to adopt a systematic approach to intervention that ensures a consistent and efficient management policy the entire housing stock.The goal of this research is to develop a tool that can help public administrations to analyse their housing stock and assess a simple, fast and automated intervention. The instrument is applicable in particular to school buildings that represent the majority of the building stock owned by local government. Through simple input information, the local authority can assess the energy performance of own buildings and understand which interventions are most appropriate for each situation under review.

2. The methodology

The tool should make immediate assessment of the buildings concerned with some simple information input, indicating the percentage of reduction of energy consumption for heating and the associated reduction of CO_2 emissions, following the improvements proposed.

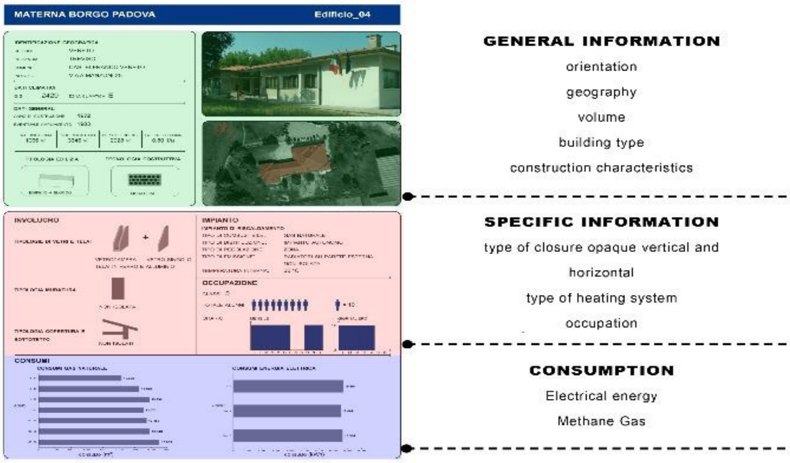

Fig.1 - Filing buildings

The development of the tool was enacted in a case study in the Municipality of Castelfranco Veneto. In particularthe research focus on 21 schools with different levels that represent the majority of the building stock owned by the Municipality. The selected sample of buildings have been filed [Fig.1] using information derived from surveys and from the archive documentation, and then it was divided in homogeneous groups, depending on the geometric and constructive characteristics, so as to optimize the procedure.The methodology of the instrument consists of three levels of evaluation [8] by adopting different methodologies with different degrees of accuracy. The first two analysis give an evaluation of energy performance of buildings and the third analysis evaluates in detail the energy behaviour of the building-plant system sample.

2.1 First analysis: the methodology ENEA –FIRE

The analysis [3] consists in the calculation of IENr normalized energy indicator and evaluation compared to the benchmarks on a basis. The indicator is calculated using the consumption , the heated volume and degree days of the location where the building is situated . The fuel consumption are strongly influenced by two parameters: the daily hours of operation of the school and the shape of the building.

$$\mathrm{IENr} = \frac{\mathrm{C\ x\ Fe\ x\ Fh\ x\ 1000}}{\mathrm{V\ x\ (GG)}}$$

C = Total annual consumption school (kWh_t).
Fe = normalization factor of the consumption due to the shape of the building (S / V).
Fh = normalization factor of consumption after the time of operation of the heating
V = Total gross heated school (m^3).
GG = Day Degrees conventional locality where the school is located(Castelfranco Veneto = 2429 GG, D.P.R 412/93).

The analysis was done for the 21 buildings of the study sample for a period of seven thermal: from 2007/2008 to 2013/2014. The IENr calculation was made previously using the value of the degree-days conventional proceeds from DPR 412/93, then the calculation was repeated using an actual value of the reporting year. To highlight any anomalies a percentage value calculated the difference between the value of IEN_rindicator of each annuity and the average value of the seven years analysed. An excessive difference in the values it would require a more detailed investigation of the relevant year to highlight the causes. According to the Index Energy Normalized heating (IEN_r) and the educational level of the school building (nursery, primary and secondary of the first or second level) the energy behaviour of the building-plant system is evaluated throughclasses [Fig. 2]: good behaviour, sufficient or insufficient.

$Wh_t / m^3 \times GG \times$ anno

	Buono	Sufficiente	Insufficiente
Materne	minore di 18,5	da 18,5 a 23,5	maggiore di 23,5
Elementari	minore di 11,0	da 11,0 a 17,5	maggiore di 17,5
Medie, Secondarie Sup.	minore di 11,5	da 11,5 a 15,5	maggiore di 15,5

Fig.2 -IENrrating

In case of "good" value, the building should present efficient system and good management. It could achieve improvements by using technologies and innovative management methods. In "sufficient" class, the school presents average value with no significant waste of energy, although it’s possible to increase its energy efficiency, especially for higher values. For "insufficient" class, it’s essential to extend the diagnosis to identify the actions of both technological and managerial best suited to the specific situation.

2.2 Second analysis: Epi index

The second analysis proceeded to the calculation of the energy performance for space heating of the building and its comparison with the limit value, as specified in the Presidential Decree 59/2009. This index, in the case of school buildings, then the category E.7 (DPR 412/93), expresses the primary energy consumption for space heating for the gross volume. As in the first analysis of the Epi limit the calculation was carried out with the value of the degree-days conventional and using an actual value of the year in question. The index is made by comparing actual energy consumption with the heated volume. In the specific case the consumption is registered in m_3 of methane for which the provision is made to turn it into kWh_tdue to the calorific known. For which:

$$EPi = \frac{C}{V}$$

C = Total annual consumption school (kWh_t)
V = Total gross heated school (m^3)

The values obtained don't allow a direct comparison of all buildings belonging to the study sample, since the limit value of the Epi is associated with each building by using the morphological characteristics. Then it was calculated the percentage difference between the Epi of each building and its Epi limit obtained by the linear interpolation of the values indicated by the Legislative Decree 192/2005, amended according to the form factor of the building and to the degree days of the location.

2.3 Third analysis: detailed analysis for homogeneous groups

The third review analyses in detail the buildings after the previous preliminary assessment. To facilitate this analysis the school buildings have been divided into groups according to their energy behaviour. The criteria for grouping is given by the most important variables in energy performance: the morphological type ("wings","uneven", "courtyard", "block" and "contiguous")and construction technology ("masonry","reinforced concrete" and "other"). This methodology allows to identify some representative building for each homogeneous group [Fig. 3], analysing deeply the performances, becoming the base for the considerations in all buildings of the same group.

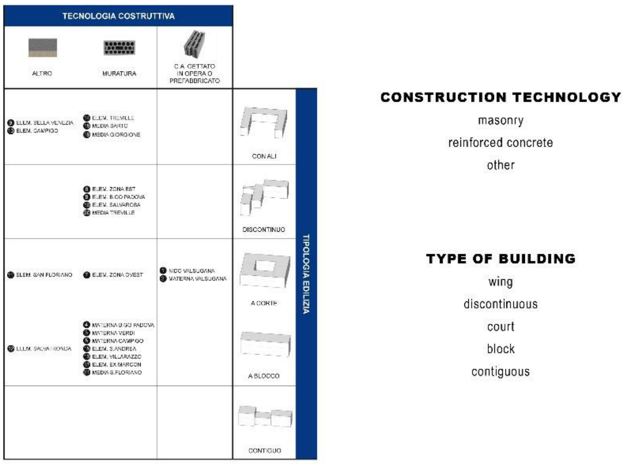

Fig. 3 - Homogeneous groups

A preliminary filing has been prepared for every building, highlighting through inspections and archival research the information of geometric shape and performance, the related plant systems and their operation, usage data by defining the occupation and internal loads. Subsequently, collected information for each building type has been translated into a mathematical model ableto simulate the energy behavior with dynamic conditions of the building installation throughthe use of specific software. The mathematical model was created by inserting the known data from previous analyzes and other proceeds according to UNI TS 11300 part 1 [6] and the 2 [7]. For this operation has been used Energy Plus as simulation software energy in dynamic mode and Design Builder as a graphical interface. To increase the goodness of the results, the mathematical model was calibrated with data of actual consumption.

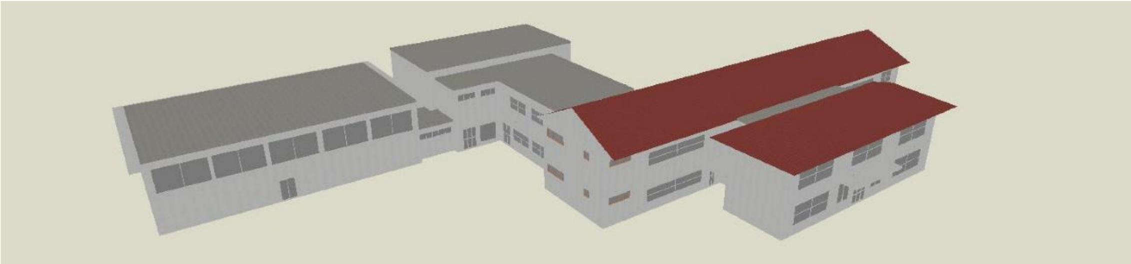

Fig. 4 - Mathematical model of energy simulation in dynamic conditions

The mathematical model was built and calibratedand then it was developed a direct and precise evaluationabout the best effective and profitableimprovements. Various kindsof energy measures for intervention were analysed and were evaluatedin order to minimize energy consumption, CO_2 emissions reduction, annual cost savings and simple payback time [Fig.5].

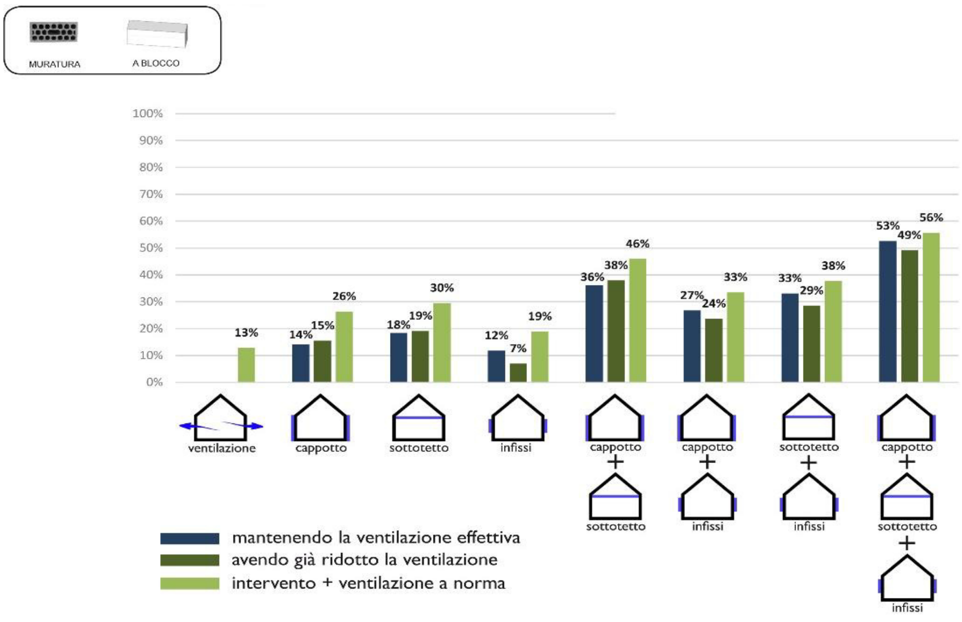

Fig. 5 - Proposed redevelopment energy

3. The instrument

It has created an easy use to make it easy to understand the methodology and to support local authorities, that often are unable to perform an analysis of the energy behaviour of their buildings due to cost and lack of internal technical resources. This tool requires easy data input, such as the morphological type of the building, the construction technology and theannual consumption of fuel for heating. The instrument provides output as indications about the best interventions that give energetically improvement and quantify the potential financial and environmental savings, providing also investment return. [Fig. 6]

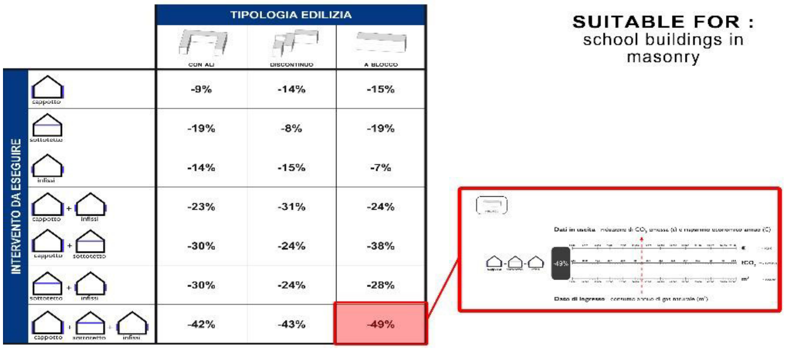

Fig. 6 - Example of energy assessment with the simplified tool

4. Conclusions

The research represents a useful methodology to analyse the existing buildings through simple data input. The methodology provides support to local government to assess the energy performance of their buildings easily and fast. For each situationthe instrument is able to provide the most affordable interventions for energy improvements. The instrument is extremely topical, reproducible at the local, regional or national level and applicable to all Italian school level. In next step of research, the instrument will implement new climate and new building types according to the chosen scope. It’s useful to remember that the goodness of the final resultsis strongly influenced by the care with the grouping of buildings in homogeneous groups.

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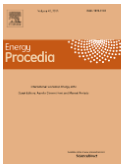

Biography

Alessandro RighiResearcher atthe UniversityIUAVofVenice where heconducts researchon issues ofenergy conservationand renewable energy.Competent in sustainablearchitecture, evaluationof buldings energy efficiency,in particularof school buildings,and energy planningthroughthepreparation ofSustainable EnergyAction Plans.