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Analysis of energy consumption of different typologies of school buildings in the city of Matera (Southern Italy)

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Abstract

School buildings constitute an important part of the non-residential building stock, because students and teachers spend much time in these rooms. This paper presents the outcome of a study on the energy performance of five different school buildings located in Matera city (South Italy). The analysis is aimed at calculating the energy requirement in accord with UNI TS 11300, comparing the results with dynamic analyses (using the Energy Plus method) and the effective energy consumptions. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649956.
The analysis has confirmed the best precision of dynamic method respect the stationary one, with an error estimated of about the ten percent compared to the real consumptions. We also presented the energy auditing interventions for all schools and evaluate the incidence of the envelope and thermal system on energy consumptions.

Keywords: School buildings, Energy performance buildings, dynamic method, energy auditing.

1. Introduction

A major part of the public non-residential building stock is constituted from school buildings. The indoor environmental and energy performance in these buildings are important for assuring the health and productivity of students and teachers. Different analyses shown in literature demonstrated in many cases that these buildings present a poor indoor air quality and consume a large amounts of thermal energy, because no energy saving measures were applied for schools operation [1,2,3,4,5,6].
This research study the energy performance of five different school buildings located in Matera city (South Italy). The analysis is aimed at calculating the energy requirement in accord with UNI TS 11300, comparing the results with dynamic analyses (using the Energy Plus method) and the effective energy consumptions. We analysed the differences between the results with method UNI TS 11300 and dynamic method, evaluating the gap with the effective consumptions. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649956.

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2. Energy analysis of different school buildings type

2.1 Description of the project

The research described here aimed to analyze, evaluate and improve the energy consumption of five different school buildings located in the municipality of Matera (Southern Italy). . Matera is the capital city of the homonymous Province of Basilicata (southern Italy), characterized by a Mediterranean climate with the presence of mild winters and hot summers; the minimum winter temperature is -2 degrees and the maximum summer exceeds 35 ° C **.**The buildings analyzed were made in different years between 1964 and 1992 and with different techniques and construction technologies. The school buildings analyzed are: Technical Institutes I.T.C.G. "A. Olivetti" (volume 23000m^3), I.P.S.S. "I. Morra" (volume 14093m^3), I.M.S. "T. Stigliani" (volume 6048m^3), Scientific Liceo "D. Alighieri" (volume 27400m^3) and Scientific Technological Liceo I.T.I.S. "G. B. Pentasuglia" (volume 12700m^3). Four of the five buildings have been realized before the law 10/91, and so have envelopes without air space and thermal insulation. Instead, only one I.T.I.S. has been realized with a wall made of a double layer of clay interposed by an air space not ventilated and plastered the both sides of the masonry with lime plaster and cement. This study was funded in part by the Province of Matera through a special convention and is part of a larger study on the diagnostic efficiency of the public school heritage of the Province of Matera. The methodology of assessment and energy analysis of building was made considering an integrated approach consisting of analysis according to UNI TS 11300 and analysis under dynamic conditions by Energy-Plus method [7]. The results were then compared with the actual consumption averaged over a period of four years (2009-2012) by evaluating the deviation with respect to the two types of analysis. The validation of the methodology by Energy Plus for massive buildings was presented in [8].

3. Diagnostic and Energy analysis: Result and discussion

4.1 Monitoring and Diagnosis

In the process of energy audits; measurement and monitoring activities and are essential to achieve a diagnosis as much as possible in line with reality and at the same time to minimize the error in the next phase of construction of the model in the calculation code. In this work the activities of in-situ measurement can be summarized in two phase: a first step of detection of the special technical and technological issues (volumes, thicknesses envelope; thermal system characteristics; etc.); in the same phase through the use of a infrared thermal camera were detected thermal bridges. A second step of in-situ measurement of the conductance in work through non-invasive methodology described by UNI EN ISO 9869 involves the use of a heat flow meter and four resistance thermometers. The sensors were mounted in such a way to ensure a representative result of the entire wall element; in this connection the heat flow meter has been mounted on the inner surface of the element because is the side with more stable temperature, avoiding the proximity of thermal bridges and heat sources. The main thermal bridges encountered, in addition to those of form, were: lack of thermal insulation on the bearing structures, junction frame-masonry and rolling shutter box. The measurement campaign was made in the winter period, as to minimize the error is essential the presence of a constant temperature difference between the two sides of the masonry around 10 °C. The measurement campaign for each building had a duration of 10 days with an acquisition intervals of 10 minutes. The parameters measured were: the surface temperature (four sensors) and the thermal flow. After 10 days we have calculated the thermal conduttance and the thermal trasmittance with the method called "progressive average" or "moving average" [8]. For the calculated the thermal trasmittance is added at the value C the normed surface resistance R_{si} (0.13 m^2K/W) and R_{se} (0.04 m^2K/W). Where the normed surface resistance are R_{si}=1/hi=0.13 m^2K/W for internal and R_{se}=1/he =0.04 m^2K/W for external. Where it was known stratigraphy envelope the transmittance was calculated in accordance with EN ISO 6946:2008. Subsequently, we launched a measure campaign in work of the combustion efficiency of heat generators according to the method described by the UNI 10389, and analyzed the bills of heat consumption (gas and/or diesel) of the years from 2009 to 2012.

3.2 Energy analysis

The numerical model was then tested both under steady state conditions according to the calculation procedure implemented by the UNI TS 11300 and both under dynamic conditions according to the calculation code implemented in Energy Plus. As for the thermal quality of the envelopes the parameter used for the comparison was Index of energy performance for envelope (Epi_{env}) calculated according to the standard UNI TS 11300. The parameter Epi_{env} is the annual need of energy required to maintain an interior constant temperature of 20 ° C in the absence of losses due to the thermal power thermal system. Next, the study focused on the building and thermal system. We calculated the Index of energy performance (Epi) : the annual need of thermal primary energy of the building calculated under intermittent conditions considering a turn-on time of the installation of 8 hours per day. (Table n. 1)

Table 1. Index of energy performance for envelope, thermal loss of envelope and index of primary energy performance

			I.T.C.G. “A. Olivetti”	L. S. “D. Alighieri”	I.T.I.S. “G. B. Pentasuglia”	I.P.S.S. “I. Morra”	I.M.S. “T. Stigliani”
Volume		m^3	23000	27400	12700	14093	6048
S/V			0,48	0,37	0,43	0,34	0,64
Index of energy performance for envelope	Epi_{env}	kWh/(m^3 year)	17,86	23,33	5,47	22,31	24,92
Thermal loss through the envelope	Q	kW	440,41	574,41	118,25	279,47	165,05
Index of primary energy performance	Epi	kWh/(m^3 year)	37,99	47,58	12,71	31,79	39,18
Energy class			G	G	D	G	G

Table 2. Annual need of fossil fuel

	Annual need of fossil fuel Dynamic method	Annual need of fossil fuel Measured value	Difference
	m^3	m^3	%
I.T.C.G. “A. Olivetti”	30955	36875	16
L. S. “D. Alighieri”	59159	70103	16
I.T.I.S. “G. B. Pentasuglia”	19241	19588	2
I.P.S.S. “I. Morra”	29570	27205	9
I.M.S. “T. Stigliani”	38804	33879	15

Completed the elaboration phase of the numerical model in under steady state conditions, the next step was to analyze the numerical model in Energy Plus. The processing of the model in dynamic conditions has allowed to obtain directly the consumption of thermal energy for heating that was compared, once converted into thermal primary energy, with the actual consumption by evaluating the deviations (tab. 2).

The low deviation obtained between the simulated fuel consumption and the actual consumption are caused by small uncertainties including the difficulty to estimating the real program operation of the system installation, the approximation of the internal loads and the not easy schematization of thermal bridges in the numeric code. A further audit was made on the value of the seasonal total average efficiency η_g checking the deviation between the two methods, the dynamic and stationary one (tab. 3).

Table 3. Global average efficiency

	Steady state calculation			Dynamic calculation		
	Annual need of energy for heating kWh	Annual need of Primary Energy kWh	Global average efficiency %	Annual need of energy for heating kWh	Annual need of Primary Energy kWh	Global average efficiency %
I.T.C.G. “A. Olivetti”	548062	1166090	47	152871	300258	51
L. S. “D. Alighieri”	626510	1278591	49	325785	573846	57
I.T.I.S. “G. B. Pentasuglia”	269525	313843	86	169670	186637	91
I.P.S.S. “I. Morra”	292127	417325	70	118860	162300	73
I.M.S. “T. Stigliani”	146642	240398	61	270945	376400	72

We can note how the values obtained with the dynamic method are higher than those obtained with the method stationary. The analysis with the dynamic method allowed us to evaluate total losses (transmission and ventilation) of the building; useful data for comparing the deviation of the two methods of analysis. The analysis of the dispersions showed a deviation between the calculation under steady state conditions and dynamic ones of 10% in favor of the calculation under dynamic conditions. The differences between the two methods are caused by the fact that the dynamic software performs calculations based on daily changes in temperature, on effects of thermal mass and on all factors that affect heat gains; while the stationary software is based on steady seasonal averages.

4. Energy Performance Strategies

The energy performance strategies of improvement were performed with the dynamic method. This method, as demonstrated by the results obtained previously, is the one that best approximates the actual behavior of the building and thermal system.

5.1 Envelope strategies

As for the energy improvement of the envelope in such a way as to achieve thermal transmittance values in accordance with the limitations imposed by the Decree 26 January 2010: Updating the Decree of 11 March 2008 concerning the buildings energy requalification (G.U. n. 35 of 12-02-2010). This improvement was performed in three successive steps, considering the improvement of the opaque envelope (step 1), the replacement of windows frames (step 2) and both solutions of step 1 and 2 (step 3).

As it can be seen from Figure 1 on I.P.S.S. “I. Morra”, the intervention on the frames ensures greater energy savings (kWh) relate to the area of intervention. Furthermore, such an intervention, compared to the application of the coat on the facades, is easy to implement and does not require the use of expensive external scaffolding.

These improvements provide a total reduction (step 3) by about 35% in the consumption of thermal energy. Table n. 4 summarizes the results for all analyzed buildings.

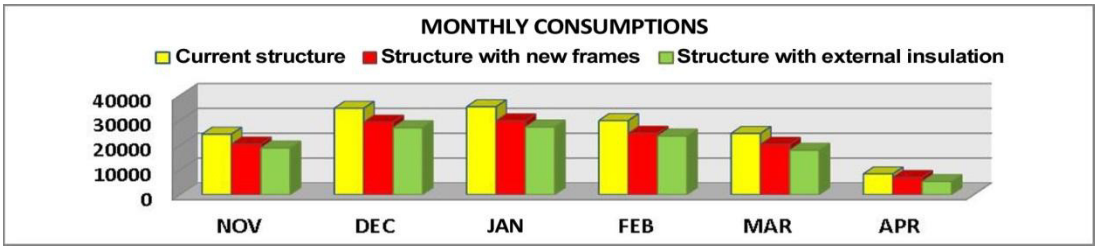

Fig.1 Energy consumption of envelope (kWh/year)

Table 4. Energy improving of envelope

Reduction of energy consumption		I.T.C.G. "A. Olivetti"	L. S. "D. Alighieri"	I.T.I.S. "G. B. Pentasuglia"	I.P.S.S. "I. Morra"	I.M.S. "T. Stigliani"
Current structure	kWh/year	1166190	1278591	313843	417325	240398
Improving transparent envelope	%	15	18	13	16	12
Improving opaque envelope	%	21	29	18	24	25
Improving transparent + opaque envelope	%	36	37	31	40	37

The school where you get the smaller savings it was the institute I.T.I.S. "G. B. Pentasuglia", because is the building made more recently than the others.

5.2 System strategies

Regarding improvements on the system, the adopted solutions were those of verify the new power to be installed after making the improvements on the envelope and subsequently replacing the existing heat generator with a condensing one with high efficiency. The next step was to replace the radiators with fan coil units and to insert thermostatic valves to increase the emission efficiency. The intervention on the system provides an extra 30% savings on heat consumption. Figure n. 2, concerning the I.P.S.S. "I. Morra", compares the improving intervention on the thermal system in conjunction with the envelope strategies.

Figure 3 instead represents the reduction of energy consumption concerning the only intervention on the terminals (replacement radiators with fan coils and addition of thermostatic valves), while Figure 4 shows the energy saving concerning to the intervention of replacement of the boilers, with a condensing one, and the emission terminals.

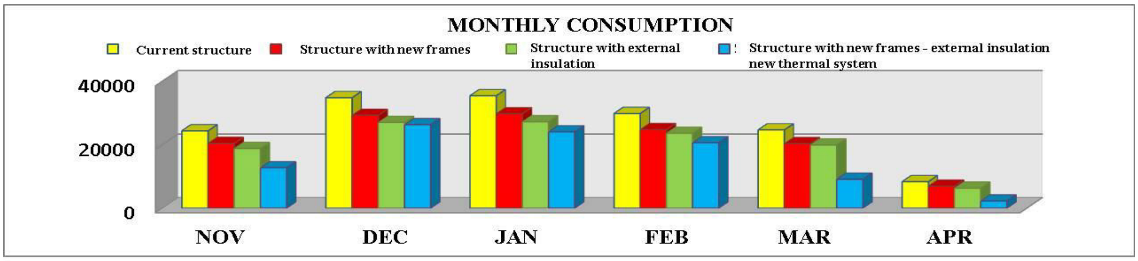

Fig.2 Energy consumption of envelope and thermal system (kWh/year)

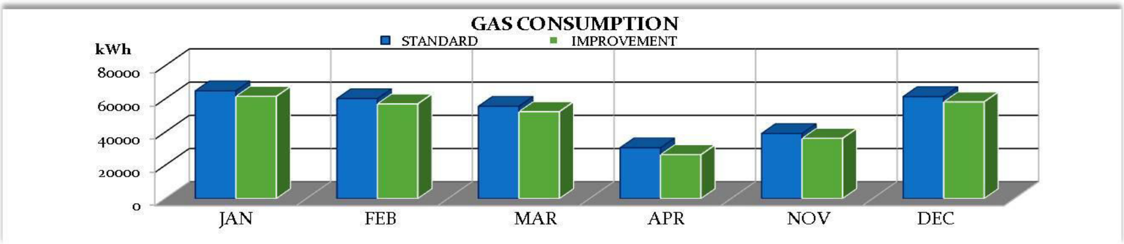

Fig.3 Primary energy consumption with replacement of terminal (kWh/year)

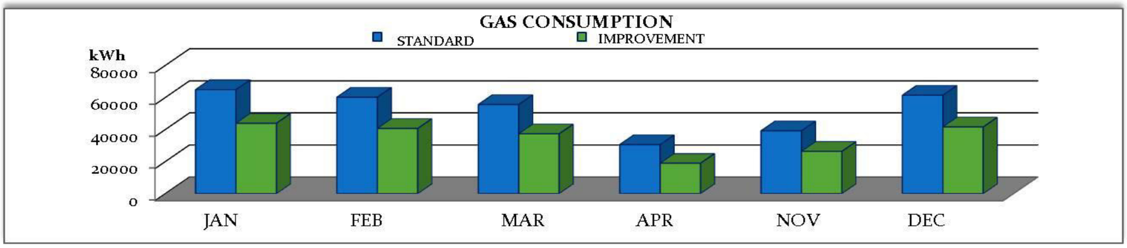

Fig.4 Primary energy consumption with replacement of terminal and heat generator (kWh/year)

As you can see the only improvement of the terminal produces a savings of only 6% of annual consumption, but if you add to that improvement also the replacement of the boiler annual savings of energy go up to about 25%. By improving the heating system it was possible to further reduce power consumption ensuring the achievement of the limits of law and a high energy class.

5. Copyright

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References

[1] L. Dias Pereira, D. Raimondo, S. Corgnati, M. Gameiro da Silva, "*Energy consumptioninschools – A reviewpaper*", Renewable and Sustainable Energy Reviews, n. 40, 2014, pp. 911–922.

[2] E. G. Dascalakia, V. G. Sermpetzogloub, "*Energy performance and indoor environmental quality in Hellenic schools*", Energy and Buildings, n. 43, 2011, pp. 718–727.

[3] L. de Santoli, F. Fraticelli, F. Fornari, C. Calice, “Energy performance assessment and a retrofit strategies in public school buildings in Rome”, Energy and Buildings, n. 68 part A, 2014, pp. 196-202.

[4] U. Desideri, D. Leonardi, L. Arcioni, P. Sdringola, “European project Educa-RUE: An example of energy efficiency paths in educational buildings”, Energy and Buildings, n. 68 part A, 2014, pp. 196-202.

[5] P. Lourenc¸ M. Duarte Pinheiro, T. Heitor, “From indicators to strategies: Key Performance Strategies forsustainable energy use in Portuguese school buildings”, Energy and Buildings, n. 85, 2014, pp. 212-224.

[6] V. De Giuli, O. Da Pos, M. De Carli, “Indoor environmental quality and pupil perception in Italian primary schools”, Building and Environment, n. 56, 2012, pp. 335-345.

[7] Energy Plus vers. 8.3, Energy Technologies Program, Energy Efficiency and Renewable Energy, U.S. Deparment of Energy. http://apps1.eere.energy.gov/buildings/energyplus/.

[8] G. Rospi, N. Cardinale, P. Stefanizzi, “Energy and microclimatic performance of Mediterranean vernacular buildings: The Sassi district of Matera and the Trulli district of Alberobello”, Building and Environment, n. 59, 2013, pp. 590-598.

Biography

Born in 1978, he graduated in Engineering in 11/03/2005 and he received PhD degree in 2010 in Environmental Technical Physics. From April 2014 to April 2015 he is Research Fellow at the Polytechnic of Bari. From July 2015 he is Research Fellow at the University of Basilicata. From September 2010 he is university teacher with part time contract in Environmental Applied Physics at University of Basilicata. Currently he is also involved in some research project affecting the energy efficient buildings, comfort indoor and renewable energy. He has published more than 30 scientific papers.