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Architecture in (R)Evolution

Bologna
9-11 September
2015

31st International
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Book of Abstracts

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TE-ENERGY FOR SYNERGY: A PRACTICAL TOOL FOR ENERGY EFFICIENCY IN THE SCHOOL DESIGN

Prof., Arch. Paola Gallo, PhD., Arch. Rosa Romano

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The Teenegy guidelines: Cover and an example of thematic contents.

WHICH ARE YOUR ARCHITECTURAL (R)SOLUTIONS TO THE SOCIAL, ENVIRONMENTAL AND ECONOMIC CHALLENGES OF TODAY?

Research Summary

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The Horizon 2020 EU program, with the pillar Social challenges, includes studies and research related to Energy sources, clean and efficient and Society inclusive, innovative and secure.

Therefore, it is necessary to rethink the future of construction sector and in particular the existing public assets, according to new challenges and new strategies.

The school buildings' safety and their energy requalification need to be primary goals in order to save this building sector, since they create an occasion to bring development, to contribute to urban regeneration, and to save the Italian construction industry from the present situation of emergency.

It is necessary to give an answer at this necessity, focusing on the implementation of a common method on decisional support for the Public Administrations, in order to find the basic technical indications and criteria to decrease the public investments in energy purchase improving the energy performances and the indoor comfort in the school buildings.

The challenge of this work is to demonstrate the effectiveness of instruments and financial resources in promoting technological innovation, in this specific construction industry, as a vehicle to transform obsolete schools buildings, in Nzeb, as indicated from the latest European legislation on energy performance of the buildings

KEYWORDS: *Energy Audit, Sustainable Schools, Energy Saving, Refurbishment Strategies, Management and Planning Instruments.*

TE-ENERGY FOR SYNERGY: A PRACTICAL TOOL FOR ENERGY EFFICIENCY IN THE SCHOOL DESIGN

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Fig 1: The Teenegy guidelines: Cover and an example of thematic contents.

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1. Introduction

Schools buildings (including universities) represent 17% of the European stock of buildings and approximately 12% of average, non-residential, energy consumption in Europe (A. V, Europe's buildings under the microscope, 2011).
In several countries, their annual energy consumption is not yet collected and no historical data for school buildings energy performance or procedures to calculate building energy performance exist. In few European countries, their annual heating energy consumption is registered and in comparison with the local building consumptions, they represent buildings with a high-energy demand: 57 kWh/sq year in Greece (M. SANTAMOURIS et al., 2007), 197 kWh/sq year in Flanders (K. AERNOUTS, K. JESPERS, 2002), 119 kWh/sq year in Northern Ireland (P.G. JONES et al., 2000).
School buildings safety and energy requalification need to be primary goals in order to save this building sector. Furthermore, those create an occasion to bring development, to contribute to urban regeneration, and to save the European school buildings industry from the present situation of emergency.
The 2012/27 European Directive on energy efficiency it is definitely an opportunity to catch for our school buildings, as demanding an annual requalification of the 3% of the public buildings heritage. Furthermore, the EU Directive, oriented to the reduction of energy demand, gives the opportunity to use school buildings to test and verify innovative technologies in building envelope and in heating and cooling plants, for energy saving.
The Lucca Province of Tuscany Region in Italy, in the absence of specific and adequate national legislation in South of Europe and in Italy, was involved into an experimental action to improve energy performance of school buildings, with the additional aim to decrease the management costs.
The analysis of the school buildings and the development of the Strategic Plan Maintenance of schools have been launched under the European research project *Teenergy Schools*. The research allowed to study in detail the energy consumptions of all school buildings of the Province and to realize a tool to manage, on the base of the EU legislation, the energy retrofit actions for the future.

2. *Teenergy School* Project, a good governance example for the school building stock in Italy

Teenergy School is a research project developed in Italy by Lucca Province and Interuniversity Centre ABITA, University of Florence. This research co-financed by the European programme Med (http://www.programmemed.eu/), involved eight partners (Interuniversity Research Centre ABITA, Granada Province, Lucca Province, Cipro University, ARPA Sicily, Trapani Province, Atene Province, Atene University.) from four strategic nations in the Mediterranean area.
The project aim was to explain common evaluation methodologies and energy analysis, in order to define an innovative strategy to promote future energy retrofit actions on existing school buildings. Furthermore, it pursued the goal of assessing a range of technological solutions, to reduce the energy requirements of the school buildings and to improve the indoor comfort into the classrooms, which can be taken to realize retrofit action or to build new NZEB schools.
Thanks to the scientific activity developed in the *Teenergy* project, it was possible to create an ICT platform shared by the project's partners. The platform's aim was collecting

data on energy audits of the schools chosen as case studies in the four country involved in the research and sharing knowledge on the design strategies to increase the energy efficiency and indoor comfort located in the Med Area, which has been summarized in:

- Five thematic brochures (http://teenergy.commpla.com/content/5-thematical-brochures)
- A Design Guide Lines (http://teenergy.commpla.com/index/brochure/teenergy_guidelines.pdf).

In particular, during the research, a simplified consumption assessing method has been developed to evaluate heating and electricity consumptions and CO_2 emissions.

Thus, it was possible to compare the energy performances data of the 71 schools that we have analysed in the four nations involved in the research, and located in different climatic conditions of the Mediterranean area. The specific objectives of the project were:

- To experiment benchmark activities for comparing buildings energy performances and defining a common Action Plan, for retrofitting as well as for new constructions.
- To design of 12 pilot projects where to demonstrate technological solutions for passive cooling, natural lighting and ventilation, integrating the use of renewable energies; also trough the organization of 3 international Workshops in Cyprus, Spain and Italy and one Campus Week in Greece.
- To create a transnational network among partners, other Public Authorities, Universities or technical bodies and schools, involving students in the phases of audits and design of the school buildings.
- To promote synergies with private operators and leader companies in this field, in order to foster technological innovation and new economic sectors.

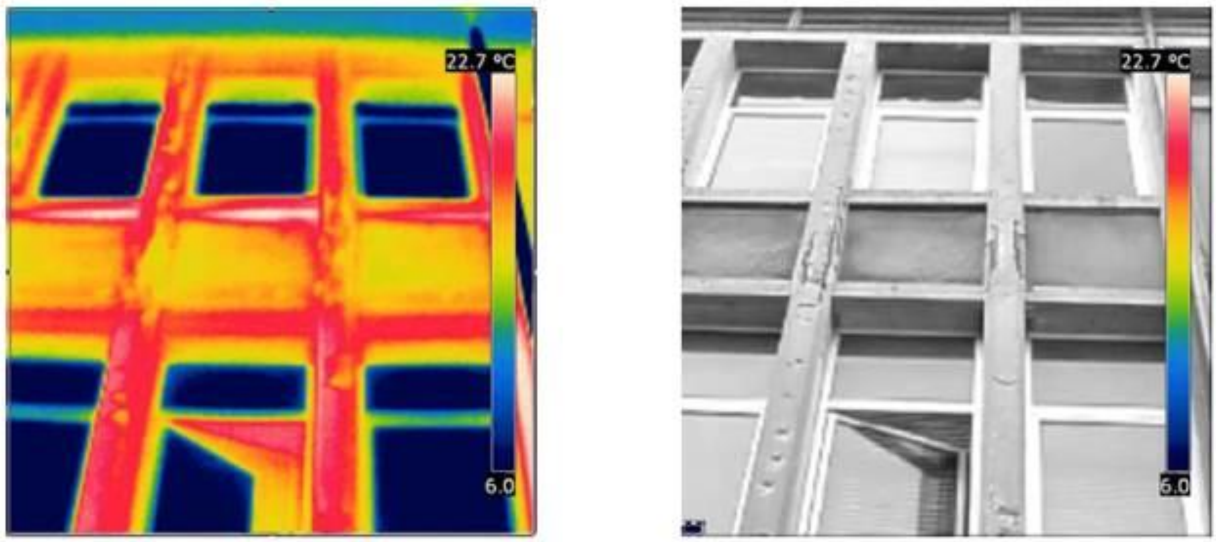


Fig 2: Carrara School: Thermal Analysis. The analysis with thermographic camera shows the presence of thermal bridges in correspondence of structural elements of the building (beams and columns)

ABITA and the Lucca Province, during the *Teenergy Schools* project, were both involved in:

- The energy analysis of 29 buildings in order to make a tool for the assessment of energy and economic retrofitting actions based on European legislation.
- The design of new school buildings projects (Secondary School Majorana in Capannori, Secondary School Barsanti in Viareggio and Technical and professional Secondary School in Castel Nuovo Garfagnana)
- The energy retrofit of existing buildings (High School Vallisneri and Technical Secondary School Carrara in Lucca).

The synergy between scientific research and the public administration's efforts, realized interesting experimentation opportunities to analyse the energy performance of existing buildings and to test new technology solutions to improve the energy performance of the school buildings located in the temperate climate of the South Europe. One of the objectives of the projects was to avoid the simple reproduction of solutions and technologies developed in the Northern countries of Europe, because these are not suitable to solve the energy problems of the buildings located in the Mediterranean area. Indeed, instead of fostering a high thermal insulation, the technical solutions should pursue the reduction of the energy consumption due to heat gains during the hot season, for example increasing envelope's thermal inertia, natural ventilation and daylighting.

3. Research Methodology

The research to develop the Strategic Plan of School has been conducted by analysing existing buildings that were divided into three climatic zones:

- Medium Valley Building's; land, temperate clime;
- Valley of Serchio Building's; mountain, cold clime;
- Versilia Building's; costal marine area, hot clime.

Buildings have been divided, for age of construction to identify the morphological and construction features and to orient the strategies of retrofitting actions, in:

- Buildings built before 1945;
- Buildings built between 1945 and 1981;
- Buildings built after 1981.

The research methodology, oriented to the development of a Strategic Plan of School, has been conducted for each building in four key actions:

1. Preliminary analysis, with thermographic analysis and energy audits for each building;
2. Energy simulation to verify the energy retrofitting strategy;
3. Cost – benefits analysis
4. Drafting of a spreadsheet to estimate the cost of the retrofitting actions and place it in a time schedule for the management issue.

Finally, we have investigated the following retrofitting strategies for the reduction of energy demand:

- Wall insulation with thermal insulation coating or inside insulation to bring the heat transmission value (U_{wall}) to the limit required by energy Italian law;
- Replacement of windows with thermal break windows that provide to bring the heat transmission value (U_{window}) to the limit required by energy Italian law;

- Envelope insulation, with insulation wall's, insulation roof's and replacement windows;
- Heating system retrofitting, with replacement of the existing boiler with a condensing boiler and installation of underfloor heating and heating system control;
- Investigation of combined above retrofitting actions, on envelope and heating system.

Moreover, for each building and for each typical classroom, the daylight luminance has been measured and, in order to evaluate the possible energy achievable by the replacement of existing lamps with smart lamps and an electronic control system of artificial light, the simulation/calculation with the software Relux has been made.

The research has been oriented to identify the best actions, in relation to costs benefits analysis, in order to give to public administration a tool that allows planning future energy retrofitting and economic actions.

3.1 Energy Audit

Teenergy Schools, operating in four different countries of the Mediterranean area has defined a Common Energy Audit elaborating a standard Questionnaire that has been used to assess the buildings' condition and energetic performances of 72 school buildings throughout the Partnership. All the collected data have been implemented on the Project's dedicated ICT platform that works as a Common Desktop of the Partnership where the results were uploaded in real time.

The audits used for this analysis contain data such as (GAITANI, N. et al, 2009):

• Annual energy consumption for space heating and cooling;
• Annual consumption for electricity;
• Area of the building;
• Year of construction of the building;
• Construction details;
• Number of students and staff;
• Installed power of the boiler and typology of the heating system;
• Length of heating and cooling season affecting the energy use.

3.2 Energy Simulations

For each building and for each strategy of energy retrofitting we have performed energy simulations with the software Thermus, made by ACCA Software. Thermus is a software that evaluates the energy requirements of buildings as indicated by the Italian legislation and UNITS 11300 technical standards. With this energy software, we have calculated:

- The thermal transmittance of the external envelope surfaces, opaque and transparent (U_{wall} e $U_{windows}$, W/ m^2K)
- The requirement of primary energy for heating (E_{pi}, kWh/m^3 year)
- The water heating primary energy requirement (E_{acs}, kWh/m^3 year)
- The total primary energy requirement (E_{pg}, kWh/m^3 year)
- The CO_2 Emission (kgCO2/m^3 year)
- The Building Energy Class

The data collected during the audit and simulation stages were processed, using the spreadsheet BENDS developed by Turin Polytechnic in European research DATAMINE. BENDS has allowed comparing energy data from the schools of the Province of Lucca with those of other European schools.

4. Findings and discussion

4.1 Building characteristics

The energy audit and the energy simulations have allowed estimating the energy performance of the school buildings involved in the research project:

• The schools built before 1945 are often located in buildings built for other uses and changed into schools in the early 1900's. Those buildings have bearing walls with thermal transmittance value about of 1.02 W/m^{2}K, the windows have big glass surfaces with wood frames and single glazes and are the major cause of heat loss (U: 4.83 W/m^{2}K). The pitched roofs are not insulated (U: 2.0 W/m^{2}K), also the ground floor slabs are not insulated and border on the basement (U: 1.56 W/m^{2}K). The heating system consists of steel boilers and radiators; there is no building management system. The building envelope has a poor energy performance, moreover, more than twice those provided by law and the schools have an energy need of about 56.62 KWh/m^3 year.• The schools built between 1945 and 1981, are located in buildings built with scholastic function, located outside the historic centre. These school buildings present the following technological features: Reinforced concrete structure; Uninsulated walls made of bricks (thickness of 25.00 to 30.00 cm) and plaster (U: 1.10 W/m^{2}K); Uninsulated roofs (U: 1.4 W/m^{2}K); Uninsulated ground floor slabs (U: 1.57 W/m^{2}K); Windows, with aluminium or wood frames and single glazed (U: 4.14 W/m^{2}K).

The building envelope has a poor energy performance and the schools have an energy need of about 57.74 KWh/m^3 year.

• The schools built after 1981 are locate in new urban areas, outside the historic centre. These buildings have been built after the first Italian law on energy saving in building (Dlgs 373/76), and show a better energy performance compared at the schools built in the previous years. In these schools: The structure is in reinforced concrete; The walls made of double layer of bricks and air gap of 5.00 cm, with the external surface finished with plaster or facing brick (U: 0.37 W/m^{2}K); The windows have aluminium frames and single gazed (U: 4.51 W/m^{2}K); The roofs are flat and made with hollow block floor - thickness of 25.00 cm - with a concrete screed -thickness of 5.00 cm - and exterior finish made with a single layer bituminous waterproofing (U: 1.63 W/m^{2}K); Ground floor slabs are uninsulated and border on the basement (U: 1.68 W/m^{2}K).

The buildings have energy needs of about 47.51 KWh/m^3 year

All school buildings have a heating system plant made with steel boilers (single-stage), power ranging from 600 to 1000kW, connected to cast iron radiators or, in the buildings built after 1960, to air-fans. The boiler didn’t produce hot water, and only a few buildings, in the bathrooms, there are electric boilers, with power of 1.5 kW, that produce hot water.

The thermographic analysis shows that the building envelope is the major cause of energy losses, because it is not insulated and the radiators are located on the external walls; also the pipes are not insulated and they represents the major inefficiency of the heating system.

4.2 Energy Simulation findings

The energy simulations to retrofit actions described in paragraph 3.2 show that:

- The retrofitting actions on walls or windows do not reduce the building energy requirement. (Tab.1)
- The replacement windows, which is one of the retrofit action done first, because is the cheapest, decrease by only 12% the building energy needs with a long payback time, which can extend beyond 15-20 years. (Tab.1)

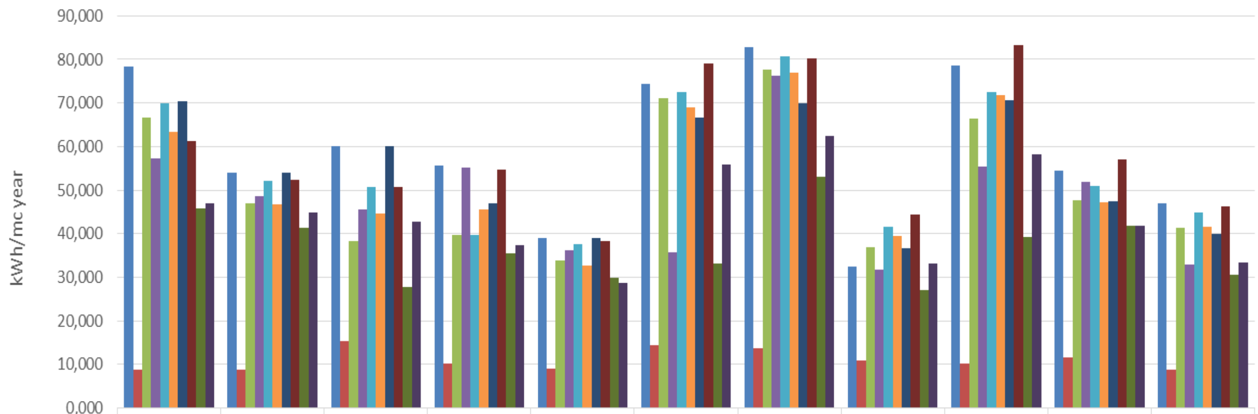
Therefore, to ensure a real reduction in energy consumptions (about 50%) and improve the energy performance of buildings, it is necessary to insulate walls and roof and replace windows in the same time. (Tab.1)

- The retrofitting action of heating systems (replacement of steel boilers with condensing boilers; installation of a radiant floor and a room control system) decreases about 25% energy needs of buildings with a cost of about € 100,000.00, which has a payback time of 35 years. However, changing the heating systems without isolating the building envelope cannot be considered a good retrofitting action, because the thermal bridges of the building envelope causing, anyway, energy losses.
- The retrofitting action of building envelope and heating system, guarantees to decreases by about 60% energy needs of buildings and to decreases by about 50% CO_2 emissions.

In the future it will be necessary to find the financing funds to promote, in the first time, of the global retrofit actions on the building envelope (opaque and transparent) and, only in the second time, actions to manage and retrofit of the heating systems. To reduce really the energy performance of the school buildings, the results of energy simulations show as it is necessary also to integrate a BMS to reduce really the energy requirements for heating, cooling and lighting.

5. Conclusions

The results of energy audit and energy simulations were used to build a work plan that will allow to a public administration to define the future refurbishment actions and to choose the best solutions of retrofit for each own school building.



	L.S. "E. Majorana", Capannori (LU)	I.S.A. "A. Passaglia" Lucca	L.C. "N. Machiavelli" Lucca	L.S."A. Vallisneri" Lucca	I.T.C.G. "A. Benedetti" Porcari	I.T.G. "L.Nottolini" Lucca	I.T.I. "E.Fermi" Lucca	L.S.P.P. "L.A.Paladini" I.P.S.S. "M.Civitali" Lucca	I.P.S.I.A. "G.Giorgi" - Sede Centrale Lucca	P.S.T. "S.Pertini" - Sede Centrale Lucca	I S A "A. Passaglia" Succursale Lucca
EPi,gl kWh/mc	78,307	54,000	60,124	55,570	38,950	74,360	82,840	32,430	78,570	54,380	47,070
Epi,gl Lim kWh/mc	8,790	8,820	15,230	10,080	9,110	14,420	13,670	10,900	10,260	11,550	8,820
EPi,gl wall kWh/mc	66,57	46,86	38,31	39,81	33,91	71,11	77,77	36,92	66,5	47,55	41,36
EPi,gl Roof kWh/mc	57,36	48,5	45,66	55,16	36,18	35,75	76,34	31,63	55,51	51,85	32,99
EPi,gl Windows kWh/mc	69,98	52,2	50,74	39,6	37,64	72,39	80,61	41,68	72,45	50,94	44,75
EPi,gl BMS kWh/mc	63,32	46,64	44,58	45,45	32,63	69,02	76,95	39,43	71,88	47,19	41,62
EPi,gl Boiler kWh/mc	70,29	54	60,12	47,03	38,95	66,67	69,98	36,69	70,59	47,51	39,92
EPi,gl Radiant floor kWh/mc	61,14	52,45	50,69	54,63	38,3	78,95	80,20	44,39	83,22	57,06	46,28
EPi,gl Envelope kWh/mc	45,76	41,3	27,64	35,42	29,83	33,13	53,03	27,12	39,26	41,75	30,51
EPi,gl Heating system kWh/mc	46,95	44,75	42,72	37,3	28,71	55,97	62,39	33,18	58,1	41,79	33,49

Tab. 1: Energy simulation results for some school buildings located in Lucca

Now the Lucca Province know exactly for each school building: the energy requirements; the technological solution to increase its energy performance; the energy saving that can to be achieved with each retrofit action; the cost for each technological solution; and finally the time to amortize the refurbishment actions.

Teenergy project has demonstrated that the public administration could go beyond the difficulties of managing a complex existing building heritage, so often damaged and inadequate in terms of energy efficiency and structural performances. Through specific resources, dedicated to strategies of planning and management, the existing buildings stock which often is in a poor state of degradation both energetic than structural, can be adequate to the requirements of European and national norms, making the interventions concrete in energy and environmental terms. The emergency that the school building sector is facing, could be transformed in an opportunity, thanks to the possibility to find new financing resources from the national and international research and financing calls.

8. Acknowledge

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