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SUSTAINABILITY FROM NANO TO URBAN SCALE

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TEENERGY EXPERIENCE: HOW TO REDUCE ENERGY DEMAND IN MEDITERRANEAN SCHOOLS

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ABSTRACT

The European Union established appropriate regulations through the Energy Performance Building 2002/91/CE and EU Directive 2010/31 aiming to ensure efficient buildings using local and national policies in relation to local and specific climatic conditions. From 31st December 2018, we have to build *zero energy public buildings* and consequently we should have zero-energy school buildings. But do we know the average total amount of energy demand of schools in Europe? The research project TEENERGY Schools has been developed with the aim to find a common method to collect energy data consumptions, to analyze the building with its plants and promote energy efficiency solutions according to national legislations, finding the most suitable technical solution to reduce energy demand in existing schools and adopting appropriate strategies to implement indoor comfort. The paper focuses on the differences between the methodologies to assess the energy consumption of school buildings in the Mediterranean Area in order to reduce the energy demand. Criticism emerged due to the fact that each European country adopted the European Directive 2002 but with significant differences. Schools are comparable in energy consumption but to compare the energy savings due to retrofitting solutions a European common tool is necessary and a methodology for collecting data has to be defined, taking into account that comparison is possible if the same instruments are used. The research project gave the opportunity to reflect on potential energy savings due to retrofitting actions on existing school buildings and also on the most appropriate technologies for new building projects. Working with technological and plant solutions adapted to the climatic conditions, the result could be very effective.

Keywords: Sustainable Schools, Energy Audit, Energy Saving, Refurbishment Strategies

INTRODUCTION

Several schools in Europe have been built between 1945 and 1980: now they represent high-energy consumption buildings. In several countries, their annual energy consumption has not yet been collected; moreover, no common procedures to calculate building energy performance exist. Only in few European countries their annual heating energy consumption is registered and in comparison with local building consumption, they represent high-energy demand buildings i.e. 57 kWh/m^{2}year in Greece [1], 197 kWh/m^{2}year in Flanders [2], 119 kWh/m^{2}year in Northern Ireland [3].

The analysis of school buildings and the development of the Strategic Plan maintenance of schools is carried out within the European research project TEENERGY SCHOOLS [4], an experimental project to improve energy performance of school buildings, with the additional aim to decrease management costs. The project, financed by the MED Programme - transnational programme of European territorial cooperation - has successfully implemented a

Multi-Issue Platform as an interactive Network for the gathering of a common database and the dissemination of best practices related to energy efficient retrofitting and new secondary schools in the Mediterranean climate context.

The Project, developed by four countries of the Mediterranean (Greece, Italy, Spain, Cyprus), has pointed out the lack of energy saving benchmarks targeted to south Europe climatic conditions and the low energy efficiency of existing school buildings taking into account not only heating but also cooling energy demand.

An *Action Plan* and a *Common Strategy* are developed on the experimentation of: energy saving techniques, integration of innovative materials and renewable energy for reducing costs and consumption. Moreover, the project set a good practice benchmark based on data from an Energy Survey in the Mediterranean countries involved in the project providing representative values and comparing energy performance in secondary schools.
The energy consumption data of 72 school buildings are collected and an instrument to assess energy and economic retrofitting actions is developed.

METHOD

The methodological approach aims to order and to systematize the stages of a common process, identifying simple tools and technical instruments to optimize the management and to define common criteria for most efficient buildings.

The research is oriented to identify the best actions, in relation to costs-benefits analysis, in order to give to public administration a tool able to plan future energy retrofitting and economic actions.

The research is conducted on 72 existing buildings in Italy, Spain and Cyprus, divided into different climatic zones and periods of construction, identifying the morphological and construction features, and to orient and address the most appropriate strategy of retrofitting actions.

Climatic zones	Land, temperate climate
	Mountain, cold climate
	Costal marine area, hot climate
Age of construction	before 1945
	between 1945 and 1981
	after 1981

Table 1: school buildings are located in different climatic zones in Italy, Spain and Cyprus and the data collected in three different periods of construction.

The research is oriented to the development of a *Strategic Plan* and it is developed (for each case study) in four key actions:

- Preliminary analysis collecting energy consumption, infra-red thermographic analysis and energy audit;
- Energy simulation to quantify retrofitting strategies;
- Cost-benefits analysis of upgrading strategies;
- Drafting of a spreadsheet to estimate the cost of the retrofitting actions and place it into an appropriate time-schedule for the management issue.

Moreover, to evaluate and estimate the relation between the visual comfort and the level of daylighting for each building and for each *typical* classroom, the daylight factor is measured; in order to evaluate the possible energy saving achievable by an appropriate integration of natural and artificial light, simulations in Relux and Radiance are made.

RESULTS

Energy Audit. Teenergy project has defined a Common Energy Audit elaborating a standard Questionnaire that has been used to assess the buildings' usage condition, thermal-visual comfort of 72 schools in four countries. All the collected data have been implemented into a dedicated Project's ICT platform [5] in which results are uploaded in real time.

The audit has been finalized to collect the following data [6]:

- 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.

Energy simulation. Energy simulations under stationary and dynamic regime are carried out on each building and for each strategy of retrofitting action. With these tools, we have mainly calculated:

- The thermal transmittance of the of the upgraded external envelope surfaces, opaque and transparent (U_{wall} e $U_{windows}$, W/m^2K)
- The requirement of primary energy for heating (kWh/m^3)
- The requirement of primary energy for hot water (kWh/m^3)
- The total primary energy requirement (kWh/m^3)
- The CO_2 Emission (kg/m^3 year)

The data collected during the audit and simulation stages are processed using the spreadsheet BENDS [7], developed by Turin Polytechnic for the European research DATAMINE [8]: it allows comparing energy data in schools.

The aim of the project was to compare data from different countries using harmonized data structure. Each project partner is able to use his own structure, which could later be translated into the DATAMINE [9] format, which, due to its common "language", allows for cross-country analyses.

The data structure includes the following quantities:

- Energy Certificate Data: basic data of the energy certificates;
- General data of the building: basic data of the type and size of the building, such as location, building utilization, conditioned floor area;
- Building envelope data: data describing the thermal performance of the building envelope, such as U-values and area of the opaque elements and window properties;
- System data: data describing the building energy supply systems, such as type of heat generation and distribution system, and air conditioning systems;
- Calculation energy demand: boundary conditions of asset rating and quantitative results;
- Basic parameters of operational rating: information on the conditions of operational rating;

- Summary of energy consumption and operational rating: summary of energy consumption and energy generation, in the first place for operational rating;
- Primary Energy, CO2 emissions and benchmarks: primary energy demand and CO2 emissions for both operational and asset rating.

Through the "DATAMINE Analysis Tool", realized in MS Excel Workbook, the exported data can be statistically analyzed. The Analysis Tool allows for comparison of parameters already present in the DATAMINE data fields, as well as of user-defined composed variables. Correlation of variables and overall statistics can be performed.

Building characteristics. The energy audit and the energy simulations need to focus on weakness of existing buildings to suggest strategies for upgrading energy performance of schools.

Italy					
Age of construction:	Wall W/m^2K	Windows W/m^2K	Roof W/m^2K	Ground floor W/m^2K	Annual energy demand kWh/m^3 year
Before 1945	1,02	4,83	2,0	1,56	56.62
Between 1945 and 1981	1,10	4,14	1,4	1,57	57,74
After 1981	0,37	4,51	1,63	1,68	47,51
Spain					
between 1945 and 1981	1,09	6,02	1,94	0,478	117,80
built after 1981	1,28	4,96	0,95	0,434	77,45
Cyprus					
before 1945	1,39	7,00	2,2	0,86	81,00
between 1945 and 1981	1,38	4,94	1,16	0,68	20,00
after 1981	1,37	4,30	0.70	0,68	18,95

Table 2: average values of 72 buildings analysed in Italy, Spain and Cyprus.

The analysis shows that the building envelope is the major cause of energy losses, because it is not well insulated, often not sufficiently massive; moreover, heating systems are not efficient: i.e radiators are located on the external walls, pipes are not insulated, the total efficiency is very low. Comparing these results with requirements of each national regulation, each country has school buildings with an annual energy demand about three times higher than the annual energy demand's limit value.

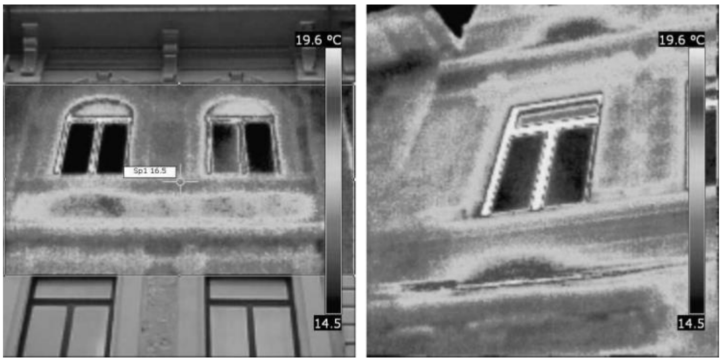

Fig. 1. IR picture of one pilot study case. The IR thermography has been used as instrument in the diagnosis phase to easily localize heat losses and consequently to investigate on retrofitting action for energy saving. This is an historical building used as secondary school in Italy. Radiators are located on the internal surface of external walls, under the windows.

DISCUSSION

The Teenergy research project merged the following problems:

a) in relation to the **energy monitoring phase**:

- Data on thermal performance of the building envelope (U-value of walls, roofs and windows) and heating system have to be measured with the same instruments;
- Difficulty to assess the IR thermo-graphic data, also using different calibrated cameras.

b) The **energy audit** was organized and conducted with a specific protocol, as a common analysis model; however, several problems incurred in data control and storage; i.e. the Bends Tool aimed to compare the data revealed that in many cases data were insufficiently collected to correctly compare the energy performance of buildings in different countries.

c) The **energy simulations**. Simulations are made to quantify the reduction of energy need due to retrofitting strategies:

- Difficulty to carry out energy simulations adopting the same methodology, as each country has adopted the EPBD and CEN standards in different ways
- Difficulty in choosing a software simulation that would allow to make a quick calculation of the building's energy demand.

Using the same simulation software, results are comparable and Guidelines on retrofitting action in schools are developed.

Simulation results show that:

- Window replacement, the cheapest retrofitting action, decreases by only 12% the building energy need with a long payback time, 15-20 years.
- Retrofitting action focused only on the thermal insulation of external walls cannot significantly upgrade the energy performance of the building.
- To ensure a valuable reduction in energy consumption -about 50%- and improve the energy performance of buildings, wall and roof insulation and windows upgrading is required at the same time.
- Upgrading of the heating system, replacing the original low efficient boiler, installing a radiant floor system with a thermostat control in each room, decreases the energy need of buildings by 25% with a cost of about € 100.000and a payback time of 35 years. However, changing the heating system without insulating the building envelope cannot be considered a

good retrofitting action, because the thermal bridges of the building envelope causing, anyway, high energy losses.

- Retrofitting of the building envelope and the heating system decreases the energy needs by 60% with a reduction of 50% of CO_2 emissions.
- Massive envelope and appropriate curtain or shading devises can reduce the overheating of 55% during the hottest seasons.

CONCLUSION

The research developed strategies applied on 12 pilot cases. The European experience shows that retrofitting action in schools in the Mediterranean area has to take strongly in account the local climatic conditions, hourly usage of the building, considering heating and cooling energy demand, avoiding overheating and use daylighting as better as possible. For new buildings, the common approach oriented to nearly zero energy buildings is possible integrating renewables, but we need common and simple tools and methodologies to assess the dynamic annual performance of the buildings, including internal gains and occupancies. We need to reduce the gap between monitored and calculated results and continue the research using the 12 pilot cases to measure the effective comfort level and energy consumption after retrofitting actions.

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