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Paving the way to nearly zero energy schools in Mediterranean region- ZEMedS project

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Abstract

The present article deals with the current situation of school buildings in four Mediterranean countries (France, Greece, Italy and Spain) as regards the energy performance and indoor environmental quality, in the frame of ZEMedS IEE Project. ZEMedS focuses on the renovation of schools to nearly Zero Energy Buildings (nZEB) in the Mediterranean, an area which represents 17% of EU-27 population. EU energy policy encourages Member States to start converting building stock into nZEB and public authorities to adopt exemplary actions. A holistic approach should combine measures to achieve high energy performance and indoor environmental quality. ZEMedS aims to cover a complete renovation path, tackling strategies for the envelope, the systems and renewable energy applications as well as the energy management and users' behavior. In this context, the first results are presented with case studies of school buildings that have been analyzed in terms of the energy efficiency and cost optimality so as to define a detailed renovation action plan.

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Keywords: Mediterranean schools; nZEB; Energy performance; Building retrofitting

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1. Introduction

As the current European legislative and building industry looks toward more energy efficient design, with the eventual goal of nearly zero energy use, additional tools and measures are needed. The commitment to implement energy efficiency in buildings requires efforts from all Member States (MS) through the adoption of suitable regulatory and policy instruments. The Energy Efficiency Directive (EED, 2012/27/EU), [1] alongside with the Energy Performance of Buildings Directive (EPBD, 2010/31/EU), [2] recast, set requirements for MS to develop long term renovation strategies for their national building stocks.

ZEMedS project, [3] focuses on the refurbishment of Mediterranean schools to nZEB. The project covers a complete renovation path, tackling strategies for the envelope, the systems and renewable energy applications as well as the energy management and users' behaviour. In this context, the first results are presented with case studies of school buildings that have been analyzed in terms of the energy efficiency and cost optimality so as to define a detailed renovation action plan.

The objective of this article is to contribute to the ongoing development of a methodology on how to achieve energy efficient and cost optimal nearly zero energy schools while ensuring the IEQ aspects.

2. Energy performance of Schools in 4 Mediterranean Countries

2.1 Spanish School Buildings

Spain is progressively implementing the European Directives related to energy efficiency in building. As regards the nZEB, a roadmap is to be delivered even if currently no national labels exist in this approach. Concerning the best practices, some initiatives are in place to reduce energy consumption in schools, regarding mainly the use and management of the building (Spanish NREAP, 2010) [4]. Nevertheless, there is no school which has been identified to be renovated following a holistic approach and reaching very low energy consumption. The lack of data as to energy performance of current buildings is an important barrier when it is to renovate the built stock. In addition, the present indoor conditions in many schools do not satisfy the minimum standards (low ventilation rates, overheating, glare problems, etc.). A program to carry out energy and IEQ assessments in schools would constitute a good option to provide data to a “Schools observatory” or even a “Buildings observatory”. Despite that, some available information on mean energy consumption in 354 Catalan schools, have shown a wide range of values, 68- 122kWh/m^2/year, the thermal contribution ranged between 60-90%. Buildings built before first thermal regulations in force are generally supposed to consume more energy than the recent buildings. However, in some cases the use of new technologies, has led to a situation where often schools built last decades consume more than that from the 60-70’s.

2.2 Greek School Buildings

In Greece, transposition of the European Directive 2009/28/EC took effect in June 2010 by the national law N.3851/2010 on RES (FEK 85/A/4.6.2010). All public buildings by 2015 and all new buildings by 2020 should cover their primary energy consumption from RES, combined heat and power, district heating or cooling, and energy efficient heat pumps. The latest Greek energy regulation exacts from the 2010/31 EPBD recast was laid out on February of 2013. This law describes a more command and control approach and also encompasses the 2020’s nZEB time-restriction. However, research has to be done to define the Greek roadmap for nZEB, with numerical indicator for energy demand and the share of renewable energy sources. So far, there is not any national law that embodies the 2012/27 EED as far as renovation rates of public buildings are concerned. Greece currently has 15,446 schools of which 4,500 are over 45 years old. The total energy consumption of school buildings is around 270,000 MWh. As of 2011, in order to get a new building permit it is necessary to achieve an annual solar fraction of 60% for sanitary hot water production from solar thermal systems (Greek NREAP, 2010) [5], or demonstrate the technical difficulties that prevented compliance. New buildings and existing buildings undergoing major renovation must be able to obtain a class B energy certificate upon completion and are required to have certain minimum U-values and heat recovery in central air-conditioning units. According to the scientific research and literature, the average energy consumption in

Greek Secondary Schools was bill-based estimated at 16kWh/m²/y for electricity and for space heating with oil at 68kWh/m²/y, (Gaitani, 2010) [6]. The mean energy consumption has been categorized per climate zone with a range from 49kWh/m^2/year up to 90kWh/m^2/year (Dascalaki, 2012) [7]. For Greek Schools, the School Building Organization (SBO) is credited by the national budget for all the expenditures related to infrastructure throughout the country. SBO is undertaking the construction of schools through the alternative finance method of PPPs.

2.3 Italian School Buildings

Italy adopted the EPBD-Recast Directive in August 2013 but the decrees (action plan and definitions) are still missing. Consequently this decelerates the diffusion of the nZEB concept, as the technical regulation currently in use is still the one related to the previous Directive 2002/91/CE – EPBD. The regulation constraints refer mainly to heating consumption, while for cooling only a few aspects are considered. More than 60% of Italian school buildings were built without any energy-related regulation in force (prior to 1976) and less than 10% were built after the adoption of the Law 10:1991 which is the first regulation in Italy introducing clear constraints about energy efficiency. At present, the lack of proper energy management may often lead to the condition in which during mid seasons the heating system is on but the school users open the windows. The great majority of schools are public, and as the public bodies facing a lot of economical problems in the last years due to the financial crisis, the possibilities for deep renovations are not many. The status of school buildings is getting worse however there is a vast lack of funding. Moreover, a great number of school buildings would need a seismic advancement, which in some cases is considered more critical than energetic upgrading.

2.4 French School Buildings

In France a series of targets have been set by the Environment Round Table and implemented in law since 2009. The widespread development of new, low consumption buildings has been encouraged, with the next step being the development of positive energy buildings by 2020. Extensive renovations of the existing building stock are in progress, with the goal being about 400,000 renovations per year (Ecofys, 2013), which will lead to a 38% reduction of primary energy consumption by 2020. Public buildings are to be renovated to achieve a minimum reduction of 40% in energy and 50% in greenhouse gas emissions within 8 years (French NREAP, 2010), [8]. When it comes to renovating a school the decision makers are the local authorities. However, they often do not have information about the energy consumption or indicators to assess comfort in their buildings. Thus, the decision to renovate a school is not always dependent on the level of consumption of the building but actually, is a political choice. Nevertheless, when a renovation project is approved, the local authorities in collaboration with a technical team (architects and consultants) set the goals for energy efficiency, indoor comfort level and budget of the operation. In addition, other induced work is necessary and can have a significant impact on the budget of the project. Certainly, additional regulatory constraints related to the accessibility of the disabled or fire safety must be taken into account. As the present thermal regulation for existing buildings does not include an nZEB goal, is up to the owners to set the target at the beginning of the project.

In France, especially in Languedoc-Roussillon, the first examples of successful renovation are becoming increasingly known. They were initiated and financially supported by the Languedoc -Roussillon and ADEME through calls for proposals. They gave a good example of how the project should be managed in terms of energy performance and how to take into consideration summer comfort. Nevertheless, the accurate results will be derived in the future and current quantitative indicators are missing.

3. Technical and Financial Toolkit

To facilitate the understanding of design and construction decisions on the rising cost of energy, to set up a common nZEB strategy and to analyze the available funding resources, this study proposes an integrated Technical and Financial Toolkit.

The main aim is to assist the energy managers, the regional public institutions, the decision-makers, the building designers, the contractors and the other professionals at different stages of their activity relating to systematic energy management in buildings, to implement nZEB renovation initiatives at schools. The Toolkit which has being developed by the joint collaboration of the ZEMedS Project Consortium, incorporates detailed information on the benefits, technical strategies, available technologies, regional perspectives, public and private funding mechanisms and best practice studies on nZEB renovation of schools.

As there is no clear definition of nZEB concept, ZEMedS's Toolkit intents to clarify and unify various definition of nZEB, identifies main obstacles and restrictions that face its application and analyses possible social, environmental and economic impacts. Going one step further the ZEMedS's Toolkit attempts to set-up some requirements related to the annual energy balance, the share of RES and the IEQ issues for the renovation of MED Schools. In brief:

- Requirement 1: C_{PE}-$Prod_{RES} \leq 0$ The annual Primary energy (PE) consumption (for heating, cooling, ventilation, DHW, cooking, lighting and appliances) should be balanced by local RES supply.
- Requirement 2: $C_{FE} \leq 25kWh/m^2y$ The annual Final energy (FE) consumption (for all uses except DHW & cooking) per conditioned area should be less than $25kWh/m^2y$
    1. For Heating/Cooling and Ventilation: $C_{HVAC} \leq 20kWh/m^2.year$
    2. For Lighting: $C_{lighting} \leq 5kWh/m^2.year$
- Requirement 3: Indoor air quality should be guaranteed (with $CO_2 \leq 1000$ ppm) and the number of hours with indoor temperature above 28ºC should be less than 40 hours, annually during occupancy

Due to lack of funding mechanisms that cover the nZEB renovation, the toolkit has also identified available national/international financial resources and instruments, and has set-up some recommendations that help decision makers in the designing of future governmental budgetary allocation channels that cover nZEB costs.

4. Case studies

Following a deep renovation strategy, different packages of measures have been examined initially to four schools as case studies. The energy performance of the selected school buildings was calculated using the Energy plus simulation program [9].

A number of measures which deal with the building envelope and energy systems, were taken into account and are listed below:

- Renovation of the façade: External wall insulation system avoiding thermal bridges (with additional application of cool coating products)
- Renovation of the roof: (1) For terrace roofs, external roof insulation system including wind/moisture barriers with new tiles (cool roofs applied in two cases), (2) For pitched roofs with unheated space under cover, insulation system applied internally
- Replacement of existing windows with upgraded ones
- Installation of external solar protections
- Replacement of existing lighting with LED
- Installation of ventilation system ((a) natural, (b) mechanical without heat recovery, (c) mechanical with heat recovery)
- Change of heating /DHW system
- Installation of PV systems

The measures were analyzed in order to comply with the ZEMedS nZEB requirements and cost optimal approach.

The thickness of the insulation together with the windows quality, were examined step wisely, as fundamental variants.

Table 1 Basic variants related to the examined U values of walls, roofs and windows

U thermal transmittance (W/m^2K)	Variant 1	Variant 2	Variant 3
Walls	0.40	0.30	0.20
Roofs	0.30	0.22	0.15

Windows and external doors	1.80	1.50	1.30-1.40

An example of the results of the energy simulations for different packages as applied to one of the four case studies is shown in Figure 1. The measures that were examined to the ITC Benincasa school, which is situated in Ancona, in Italy, included: the envelope renovation, two kind of new heating and DHW systems (geothermal and biomass boiler) and other measures like solar protections, lighting replacement, ventilation with heat recovery and PV systems. A number of simulations, with Energy plus, were performed for 12 variants. The variables presented here correspond to:

- variant 7: variant 1+(geothermal)+(solar protections, lighting replacement, ventilation with heat recovery and PV systems)
- variant 8: variant 2+(geothermal)+(solar protections, lighting replacement, ventilation with heat recovery and PV systems)
- variant 9:variant 3+ (geothermal)+(solar protections, lighting replacement, ventilation with heat recovery and PV systems)
- variant 10:variant 1+(biomass boiler)+(solar protections, lighting replacement, ventilation with heat recovery and PV systems)
- variant 11:variant 2+(biomass boiler)+(solar protections, lighting replacement, ventilation with heat recovery and PV systems)
- variant 12:variant 3+(biomass boiler)+(solar protections, lighting replacement, ventilation with heat recovery and PV systems)

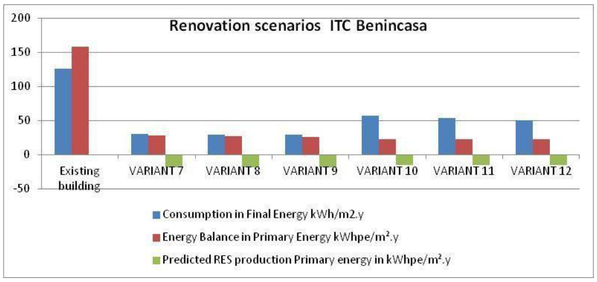

Figure 1Results for Italian school building case study

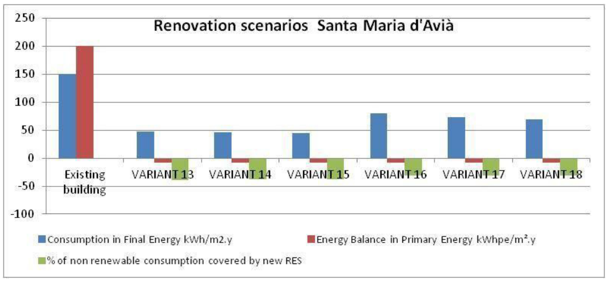

Figure 2 Results for Spanish school building case study

As showed in Fig.1. there are slightly differences between fundamental variants when the same energy system is installed. IEQ Requirement 3 is accomplished by the mechanical ventilation with CO_2 sensors in classrooms and offices. The energy balance in primary energy (PE) (Requirement 1) is reached only if a PV system is applied to cover the energy consumption from appliances. The geothermal boiler variants comply with FE of 25kWh/m^{2}y (Requirement 2).

The Spanish case study (see Fig.2) has also reached energy balance after the application of measures such as: building envelope, solar protection, lighting, mechanical ventilation with heat recovery, new heating and DHW systems (geothermal and biomass boiler), PV systems and new computers.

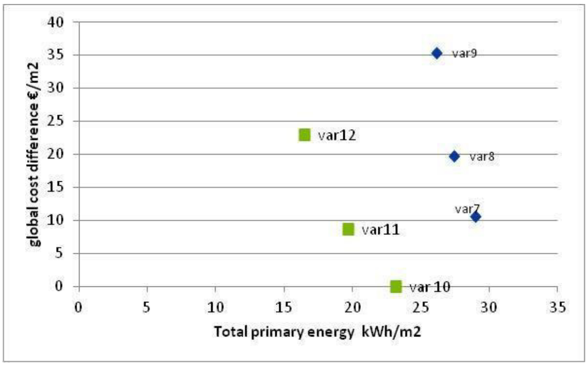

Figure 3. Global cost difference in front of total primary energy

In addition, cost optimal calculations were implemented for the packages of measures (variants presented above) following the steps indicated in Ecofys methodology [10]. An example is the Italian case study presented in Figure 3, which is a step wise deep renovation along 30 years, with discount rate of 3% considered. It gives an idea of the advantages of biomass boiler over geothermal and a difference of 20€/m^2 between examined variants.

Another two case studies of Greek school buildings, resulted in cost advantages for mechanical ventilation with heat recovery of 75% as in these cases also the corridors were considered to be ventilated apart of classrooms and offices. The FE has reached 25kWh/m^{2}y after measures in building envelope, lighting, mechanical ventilation with heat recovery and PV systems.

5. Concluding remarks

The ZEMeds project intents to elucidate the relationship between nearly zero-energy and cost-optimal measures and to develop an argumentation on how to ensure a smooth transition from current MED schools to nearly zero energy school buildings. In this context, the first results are presented with case studies of school buildings that have been analyzed in terms of the energy efficiency and cost optimality so as to define a detailed renovation action plan.

The ZEMeds integrated Technical and Financial Toolkit offers multiple best practices, techniques and methods that guide the implementation of nZEB actions in accordance to the unique necessities of each school, region and country in the Mediterranean area. Also the Toolkit attempts to set- up energy performance and IEQ requirements of MED schools with a view to achieving cost-optimal levels. As these requirements are quite ambitious an evaluation to a greater number of case studies is needed and will be the main part of the planned future work.

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