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Energy saving potential by retrofitting the artificial lighting system in the typical classroom in Greece

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Abstract
The energy consumption for the artificial lighting in school buildings is one of the main consumers of electricity. In Greece there is a large number of school buildings with quite old lighting systems using luminaires with T8 and sometimes T12 florescent lamps with electromagnetic ballast and degradated translucent diffusers. Scope of this paper is to present the benefits achieved from upgrading of the artificial lighting system of a typical classroom using available technologies from late 60's to present where due to economic crisis the public sector failed to invest on LED luminaires. This paper examines the energy savings potential by using efficient luminaires and proper planning.

The typical classroom in Greece
In Figure 1 the typical classroom in a Greek public school building [1-3] is presented. In Table 1 the lighting system used in the classroom is presented according to the year of construction. The guidelines [2] concerning artificial lighting refer only to illuminance value (300lx) while the European Norms [4] refer also to uniformity (>0,6 min/average) and glare (UGR <19). Figure 2 presents the interior of two classrooms with different lighting system.

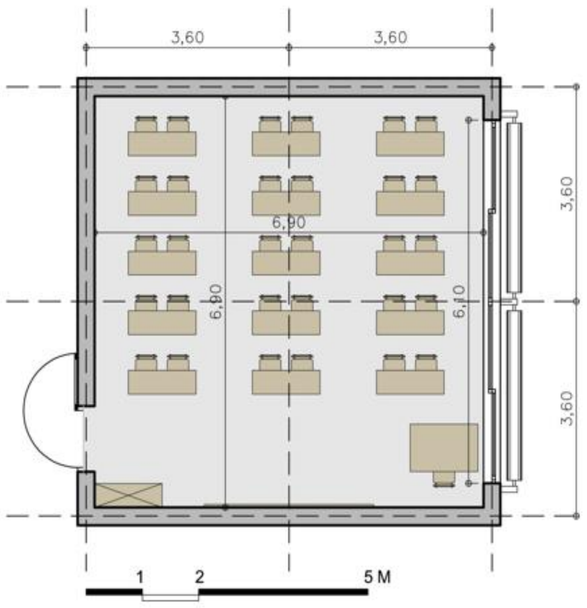

Figure 1. Plan of a typical classroom in Greek public school buildings (Height: 3,2m) [1-3]

Table 1. Typical artificial lighting system in classrooms of public domain school buildings

Building's date of construction	Type of luminaire*	Number of luminaires	Average total power of lighting system per classroom* (W)	Power density** (W/m²)
…-1970	T12 2x60W with electromagnetic ballast and milky cover (frosted diffuser)	9 to 18	2700,0	56,7
1970 -1980	T12 2x60W with electromagnetic ballast and milky cover	9 to 18	1840,0	38,6
	T8 2x58W with electromagnetic ballast and milky cover	9 to 18		
	T8 2x36W with electromagnetic ballast and milky cover	9 to 18		
1980 - 2000	T8 2x58W with electromagnetic ballast and without any cover (batten type)	9 to 12	1015,2	21,3
	T8 2x36W with electromagnetic ballast and without any cover (batten type)	9 to 12		
2000 – 2008* **	T8 2 x 36W with electromagnetic ballast and without any cover (batten type)	9 to 12	777,6	16,3
2008* ** - 2010**	T8 2 x 36W with electronic ballast and parabolic louver	9	680,4	14,3
	T8 4 x 18W with electronic ballast and parabolic louver	9		
2010 – present** **	T5 2 x 28W with electronic ballast and parabolic louver	6 to 8	470,4	9,9

*Power increment due to ballast is included, Electromagnetic ballast 25% (1960-1980), Electromagnetic ballast 20% (1980-2008), Electronic ballast 5% (2008 – present)
**Limit of power density before 9/2017: 9,6W/m² , after 9/2017: 8,4W/m² (Energy efficiency regulation of buildings, 2010 and 2017) [5,6]
***Release of Joint Ministerial Decision Δ6-B-14826-17-6-2008 [7]
****Construction with partnership between private and public body

Figure 2. Typical artificial lighting system in classrooms of public domain school buildings. Left: T8 2 x 36W with electromagnetic ballast and milky cover (frosted diffuser). Right: T8 2 x 36W with electromagnetic ballast and without any cover (batten luminaire type)

The potential energy savings
Using efficient luminaires (high efficient T5 and LED) and proper planning the total power of the lighting system is 235W when 4 luminaires T5 2x28W are used and 160W when using 4 luminaires LED 40W each. (Figure 3, left). The results are in confirmation with EN 12464-1 :2011 [4] (Figure 3, right).

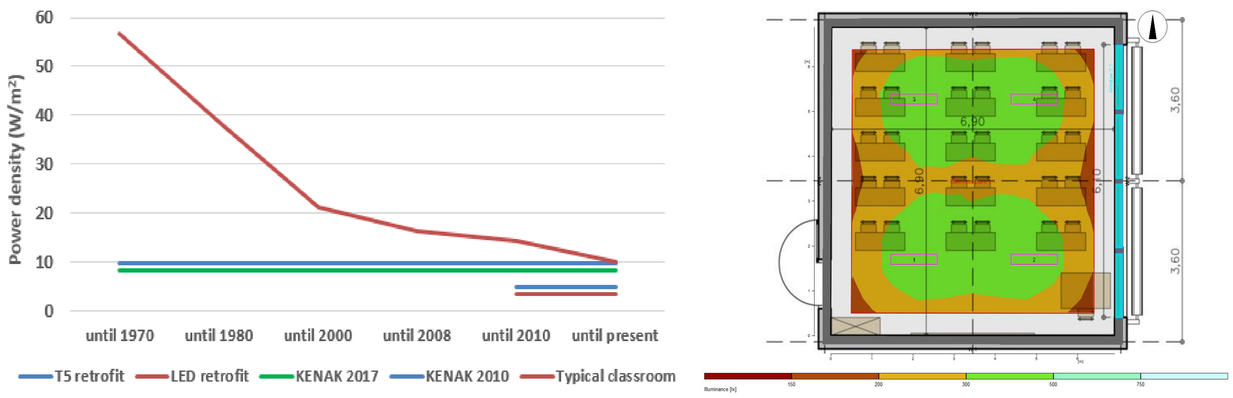

Figure 3. Left: Power density (W/m²) for typical classroom in regards the date of construction, the limits of energy efficiency regulation of buildings, 2010 and 2017, and the potential power density with high efficient T5 and LEDs Right: Photometric results using 4 LED panel luminaires (116lm/W): Average illuminance 302lx, Uniformity (min/average) 0,66, max glare UGR 19,1

Conclusions
The majority of the classrooms in Greece have increased lighting power density when compared with the value proposed by either European norms or recommendations. This is due to the fact that the design procedure was insufficient not to mention not existent. This resulted in over-illumination in most cases and a substantially increase in installed power especially in cases after 2008. Prior to that the increased lighting power was due to the technology used. Approaching the near zero energy buildings, it seems that high efficiency luminaires together with the use of daylight controls should be an obligatory option in school buildings. We plan to minimize lighting energy consumption further by the development of a low voltage grid which connects PV with luminaires.

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References
1. Buildings' Infrastructures S.A. (Ktiriakes Ypodomes S.A., http://www.ktyp.gr), Ex-Organization of School Buildings (http://www.osk.gr)
2. Guides for constructing School Buildings, 2008 Organization of School Buildings (http://www.osk.gr).
3. Bioclimatic design guidelines for school buildings, 2008 Organization of School Buildings (http://www.osk.gr).
4. European Norm 12464-1: Light and lighting—lighting of work places Part 1: Indoor work places, 2011.
5. Energy efficiency regulation of buildings (2010)
6. Energy efficiency regulation of buildings (2017)
7. Joint Ministerial Decision Δ6-B-14826-17-6-2008

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