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Daylight analysis and lighting energy management for schools in hot-temperate climates

Rana KUTLU[*1], Alpin YENER[**], Banu MANAV*, Mehmet Şener KÜÇÜKDOĞU[***]
** Istanbul Kültür University, Faculty of Fine Arts, Istanbul, TURKEY*
*** Istanbul Technical University Faculty of Architecture, Istanbul TURKEY*
**** Istanbul Kültür University, Faculty of Architecture, Istanbul, TURKEY*

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Abstract:
The aim of the study is to suggest an optimum facade design and an energy efficient lighting system for elementary schools' classroom modules for different climate types. A classroom module from the typical projects which are implemented by the Ministry of Public Works and Settlement of Turkey was analyzed, by the aid of the computer based daylight analysis program Radiance 2.0 Beta, and daylight performance was evaluated for hot and temperate climate types. The results are evaluated in terms of monthly and annual energy consumption and a proposal is made to increase visual performance and to reduce energy conservation. The proposal covers envelope design, solar control and artificial lighting system. The principles of facade design, shading device and artificial lighting system are discussed from the view point of energy conscious design for hot and temperate climate types. The study findings suggest an optimum orientation-dependant facade design for the two climate types.

Keywords: *Daylighting, lighting energy management, elementary schools' classroom module, facade design, climate type*

Introduction

Visual and thermal performance play a significant role in energy efficient lighting design. In this sense, it is aimed to maximize the use of natural light while minimizing the artificial energy loads which cover the lighting, heating and cooling systems. Besides, building envelope design has a vital importance on energy conscious design while minimizing the artificial lighting loads, active heating and cooling systems. Passive solar control system which also includes transparency ratios, is a climate-dependant issue and should be re-designed for each climatic condition (Energy Design Guidelines for High Performance Schools, 2004).

Design strategies of energy efficient daylighting systems and optimization of heating, cooling, lighting loads has become an important subject, which several research studies focused on. Saridar et.al., evaluated the impact of the facade configuration on daylight levels by examining the daylight efficiencies of several facade examples. Appropriate facade design including shading is suggested for Mediterranean climate, in order to avoid glare and reduce the lighting energy consumption (Saridar, S., Elkadi, H., 2002). A method to analyze the daylight availability in classrooms with solar control is proposed by Yener, in order to determine an optimal solution both from the visual and thermal comfort points of view (Yener,A., 2002). The study carried out by Aghemo et.al., is on the prediction of the performance of different shading devices basing on simulations. The importance of the integrated design of daylighting system with building design is highlighted in the study (Aghemo, C., Pellegrino, A., LoVerso, V.R.M., 2008). Jenkins et.al., focused on the overheating problem in school buildings by considering the climate change and suggested optimization of overheating and daylighting solutions, in order to provide the comfort conditions in classrooms while reducing the carbon emissions (Jenkins, D.P., Peacock, A.D. , Banfill, P.F.G., 2009).

Lighting quality improves students' moods, behaviour, concentration and therefore learning. Meanwhile, good lighting optimizes energy use while creating a productive learning environment. Energy efficient lighting aims the best use of natural sources as well. In this sense, one of the European directives provides rules for improving energy performance of energy related products by decreasing energy consumption %20. One of these requirements on lamps covers incandescent and tubular fluorescent (TL'D, T12) lamps, and their more energy efficient alternatives.

In 2009, a research that is conducted in Hamburg, Germany highlights the importance of energy efficient lighting. 166 students between 8-16 ages and 18 tearchers participated in the study. The effects of automation control lighting system which is designed by energy efficient luminaires and low color rendering index light sources are used to analyse students' performance. Findings of the research suggest that lighting quality has improved students' concentration and behaviour (Schulte-Markwork, et al 2009). Automation control lighting system provided 50% energy efficiency while proper luminaire selection provided 30% decrease in energy consumption.

The main aim of this study is to analyze elementary schools' classroom modules in Turkey from the view point of energy conscious design with a special emphasis on daylight analysis and lighting energy management. In Turkey, elementary schools are constructed according to the typical projects that are implemented by the Ministry of Public Works and Settlement and a manual that is prepared by Leblebicioglu et.al (Leblebicioğlu, F., Özkan, N., Kadıhasanoğlu, A., Saltan, A., Özkaya, Y., 1998). Although this manual refers to the standards and different applications from the world, there are problematical issues about the design parameters. These parameters cover the design process of the typical project implementation which is independent of location and thus can be repeated in multiple sites in various forms. Natural, physical and structural characteristics of the specific location, which constitute the data for the project's design process, including lighting, are ignored. As indicated by Gökmen et al (2007), typical project implementation shall be handled in two phases. At the first phase, typical design applications can be generated and at the second phase, site dependant design parameters which cover orientation, facade and envelope design, shall be adapted to the typical project.

This study aims to evaluate and implement energy efficient design principles for a classroom module which is taken from the typical project. In line with this objective, a proposal is offered for two climates to obtain the most appropriate orientation dependant facade configuration in terms of climatic and visual comfort conditions in a classroom module at the design of elementary schools. The proposal is composed of design principles for the facade, building envelope, shading device and artificial lighting system which are evaluated from the view points of visual and climatic comfort conditions and energy conservation.

Method of the study

In the present study, a classroom module was taken from the “Elementary School Prototype Projects” implemented by the Ministry of Public Works and Settlement of Turkey and daylight illumination was calculated by the aid of Radiance 2.0 Beta Simulation Program (Ward, G., Shakespeare, R., 1998) for the existing and the proposed envelope configuration for different orientations.

Istanbul (temperate climate) and Antalya (hot climate) were chosen as the representatives of the regions respectively. Daylight levels were calculated for the 15th day of each month -characteristic days- between September and June for the “prototype project” and the “classroom module”. The “characteristic day” was determined according to a series of calculations in a previous study conducted by Kutlu Güvenkaya (2008). In the study, means of the hourly daylight illuminance were recorded during the whole academic year and statistical tests were adopted to generalize the validity of the “characteristic day”. According to the Mann-Whitney Test results, it was determined to use the 15th day of each month in the present study.

A grid system was offered for the 12 points on the working plane at the “classroom module”. Simulations were recorded for each hour (between 7:00 – 17:00) and the results were compared in terms of the required illumination level of 300 lx. The classroom module and the grid system are given in Figures 1 a and 1 b.

Facade design proposals for the classroom modules in temperate and hot climate regions with different window directions (east, south, north, west) were developed, which provide both climatic and visual comfort conditions. Solar control systems for different orientations were designed taking into account the period for which shading is desired.

Furthermore, a new artificial lighting system with daylight responsive control system was offered in order to optimize the lighting energy consumption. Artificial lighting loads were determined in relation to daylight levels for the existing classroom module and for the proposed one. The artificial lighting system was composed of luminaire based light sensors which could be dimmed to provide the required illumination throughout the working hours. Energy loads at the classroom module were compared for both climate types. The results were evaluated from the perspective of lighting economy and visual comfort conditions. Lighting energy consumption with regard to daylight illumination and energy efficiency at the proposed module was calculated.

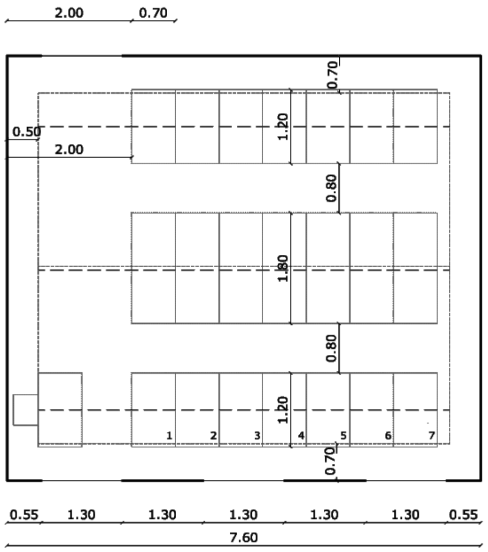

Figure 1a. *Plan of the existing classroom module*

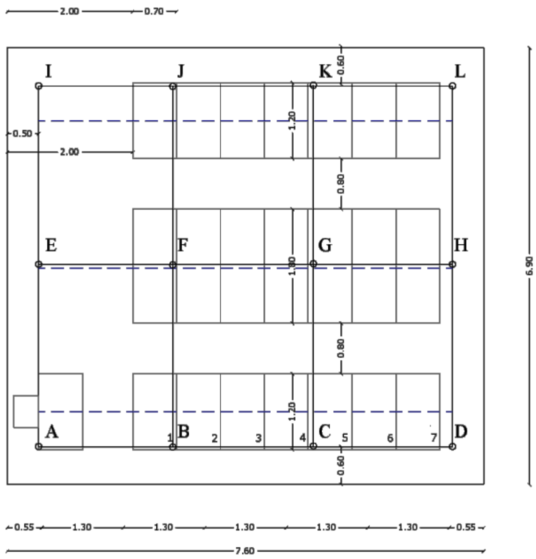

Figure 1b. *Plan of the existing classroom module with the measurement points*

General assumptions in the study

The main goal of lighting in an educational building is, to satisfy visual comfort conditions (lighting quality and lighting quantity) for its users. The general assumptions for the present study are focuses on evaluating lighting adequacy and uniformity on the working plane. The study is restricted to the following issues:

- Required illumination level on the working plane is 300 lx (Anon, CIBSE, 1994).
- Daylight availability should be maximized and complemented by artificial lighting during the daytime
- Solar control is required to avoid glare
- Artificial lighting system should be designed by considering the energy efficient design principles
- Luminaires should be mounted on the ceiling to provide uniform light distribution
- Luminaire raws are parallel to the window side and daylight responsive control should be provided

Parameters of the simulation scenario for temperate and hot climates

The assumptions and parameters of the simulation scenario are summarized in Table 1. In the study, CIE Intermediate sky was selected for the design sky model of Istanbul (temperate climate) and CIE Clear sky was selected of Antalya (hot climate) considering the sunshine probabilities and percentage of clear and overcast days of relevant locations (Enarun, D.,1996).The Turbidity Factor according to Linke is dependant on the season of the year and day time, climate zone and the region of the station. In this study Linke's monthly mean values of turbidity factor for temperate and hot climates are accepted (Aydınlı, S., 1983),(Meteotest, Bern,2008).

Table 1. Parameters of simulation scenario for temperate and hot climates

	TEMPERATE CLIMATE	HOT CLIMATE
SKY MODEL	CIE Intermediate Sky	CIE Clear Sky
LOCATION	Istanbul Latitude 41°.06 N Longitude -29°.02	Antalya Latitude 36°.53 N Longitude -30°.42
TIME ZONE	Standard Meridian 15x-2= -30	Standard Meridian 15x-2= -30
TURBIDITY FACTOR	Linke Turbidity Factor	Linke Turbidity Factor

Classroom specifications

The dimensions of the classroom module are 6.90 m x 7.60 m. x 3.18 m. The occupation time is between 7:00 and 17:00 hours. It is located on the ground floor facing alternatively to four different orientations (east, south, west and north) without any obstacles around. The daylight values were calculated for the 12 points on the grid system which is 0.50 m away from the walls and 0.67 m (Neufert, E., 1983) above the floor level. Specifications of the finishing materials at the classroom module can be summed up as follows:

- Floor (interior): stone coverings, reflectance coefficient 21%
- Walls: cream painted, reflectance coefficient 70%
- Ceiling: white painted, reflectance coefficient 80%
- Ground covering: concrete, reflectance coefficient 20%

Daylighting system of the existing classroom module

The classroom module has side windows; with a transparency ratio of 31% (for all orientations), 6 mm thick double glass with 78% light transmittance was used with PVC Frame. Daylighting systems of the classrooms in Istanbul and Antalya are the same in the typical projects. Shading elements are not used in the existing project.

Daylighting and Solar Control Systems of the Proposed Classroom Modules

In the study, the most appropriate orientation dependant facade configurations which provide climatically and visually optimal conditions in Istanbul and Antalya were identified. Viewed from the perspective of heating and cooling energy conservation, the maximum transparency ratios without insulation were determined according to the method developed by Yılmaz and the diagrams for temperate and hot climate were used (Yılmaz, Z.,1983),(Koçlar Oral, G.,1998). Daylighting system of the proposed classrooms for Istanbul and Antalya are given in Table 2.

***Table 2.** Daylighting system of proposed classrooms for Istanbul and Antalya*

	ISTANBUL		ANTALYA	
Transparency Ratio	NORTH	40%	NORTH	46%
	EAST, WEST	46%	EAST, WEST	32%
	SOUTH	46%	SOUTH	46%
Light Transmittance of Glass		78 %		78 %
Light Reflectance of Glass		14 %		14 %
Thickness		6 mm		6 mm
Window Frame	Double Glazing with PVC Frame		Double Glazing with Wooden Frame	

The proposed classroom module has a daylighting system with exterior shading elements to control the direct entrance of sunlight into the classroom. Exterior movable shading elements were implemented by considering the period for which shading is desired in accordance with the energy efficient design principles. As Figure 2 illustrates, the shading period for the temperate climate type covers a period from May to August, whereas the shading period for the hot climate starts from the mid of April to November.

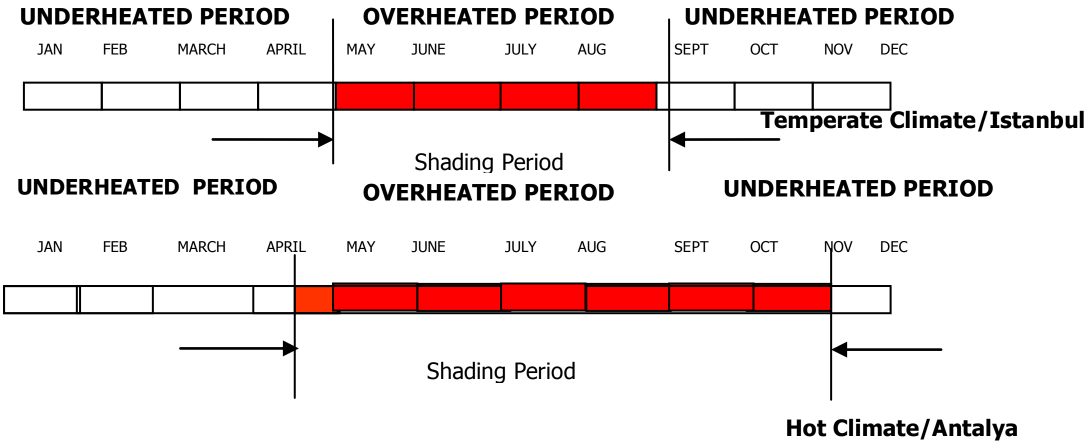

Figure 2. *Shading period for the temperate and hot climate types*

The system is designed as a horizontal multi-element movable system. Profile angles are determined according to orientation and latitude by using shading mask on "sun path charts" for 41°N Istanbul and 36°N Antalya (Zeren, L.,1962). According to the orientation, the number and the size of the multiple elements are varying. The shading devices are designed at 30° and 45° inclination.

The proposed system not only provides aesthetical and functional needs, but also it is practical from the view of material type and size, as seen in Figure 3a and Figure 3b.

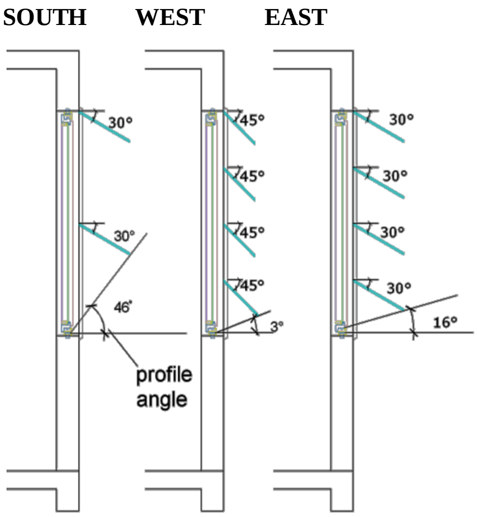

Figure 3a. *Proposed shading system for Istanbul*

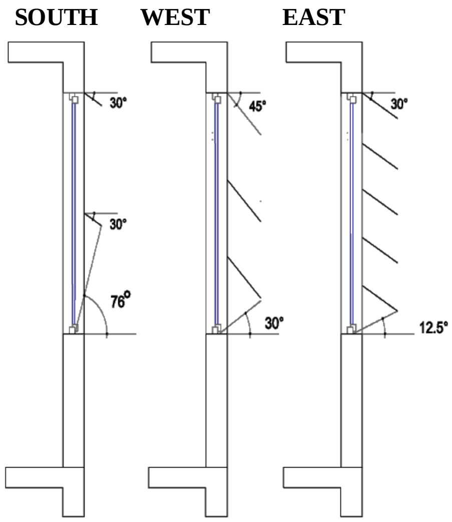

Figure 3b. *Proposed shading system for Antalya*

High reflective, light coloured, matte surfaced aluminium shading devices were selected which avoid glare problem. Table 3 gives the physical properties of the system.

Table 3. *Description of the physical properties of the proposed shading system*

Climate Region/City	Orientation	Shading Device	Slope	Number of Elements	Material	Surface Properties
Temperate Climate/ Istanbul	East	External Movable Horizontal Multi-Elements	30°	4	Aluminum	r:79 % S:50% T: 0% R:10%
	West	External Movable Horizontal Multi-Elements	45°	4	Aluminum	r:79 % S:50% T: 0% R:10%
	South	External Movable Horizontal Multi-Elements	30°	2	Aluminum	r:79 % S:50% T: 0% R:10%
Hot Climate/ Antalya	East	External Movable Horizontal Multi-Elements	30°	5	Aluminum	r:79 % S:50% T: 0% R:10%
	West	External Movable Horizontal Multi-Elements	45°	3	Aluminum	r:79 % S:50% T: 0% R:10%
	South	External Movable Horizontal Multi-Elements	30°	2	Aluminum	r:79 % S:50% T: 0% R:10%

r: Reflectance Coefficient T: Transparency Coefficient S: Specularity R: Roughnes

Figure 4a illustrates elevations of the proposed facades for Istanbul and Figure 4b shows elevations of the proposed facades for Antalya according to four different orientations.

The time intervals, for which illuminance supplied with daylight is sufficient and insufficient are determined and are presented in Table 4. When the illumination is lower than 300 lx on the working plane, supplementary artificial lighting is needed to satisfy the visual comfort conditions. At the "existing classroom module", generally the illumination is lower than 300 lx, which means the artificial lighting system is in use throughout the working hours and there is a high amount of energy consumption. However, for the "proposed classroom module", when the supplementary artificial lighting is required, the automatic lighting control system helps to maintain the amount of required artificial lighting to satisfy visual comfort conditions only by adding the lacking amount. For example, when the illumination is 200 lx, there is a surplus of only 100 lx to optimize the lighting conditions at the proposed classroom module while at the existing classroom module there is additional 300 lx.

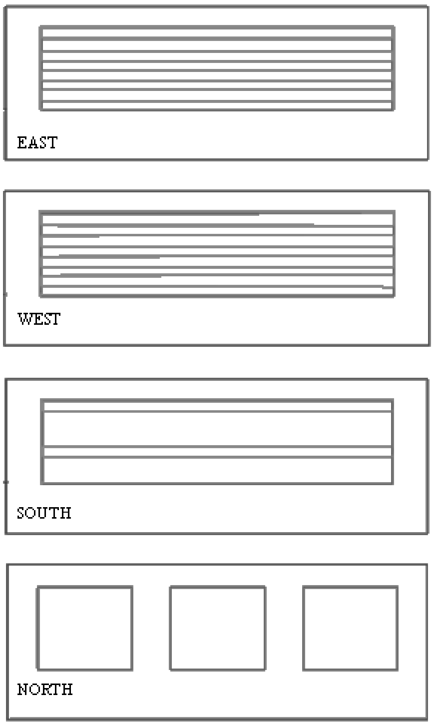

Figure4a. *Elevations of the propose facades for Istanbul*

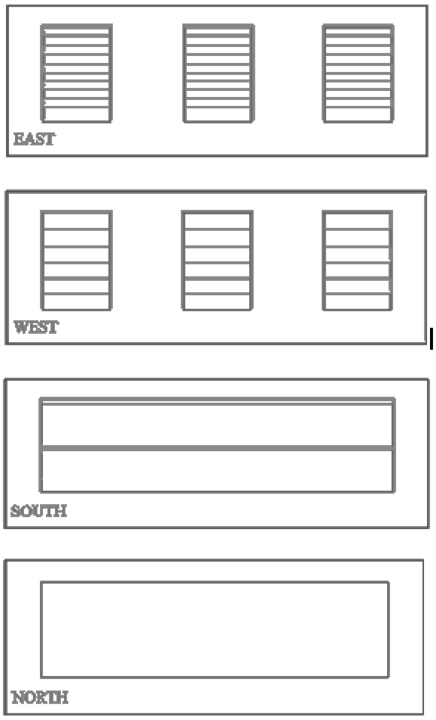

Figure 4b. *Elevations of the proposed facades for Antalya*

Table 4. *Comparison of daylight availability at the investigated classroom module.*

Table 4a. *Daylight availability at the investigated classroom module in Istanbul.*

DAYLIGHT AVAILABLITY AT THE EXISTING CLASSROOM-ISTANBUL

EAST	JAN 15th	FEB 15th	MARC 15th	APRIL 16th	MAY 15th	JUNE 15th	SEPT18th	OCT 16th	NOV15th	DEC 15th
07:00	-	-	-	-	-	-	-	-	-	-
08:00	-	-	-	-	-	-	-	-	-	-
09:00	-	-	-	-	¤	¤	-	-	-	-
10:00	-	-	-	-	¤	¤	-	-	-	-
11:00	-	-	-	-	-	-	-	-	-	-
12:00	-	-	-	-	-	-	-	-	-	-
13:00	-	-	-	-	-	-	-	-	-	-
14:00	-	-	-	-	-	-	-	-	-	-
15:00	-	-	-	-	-	-	-	-	-	-
16:00	-	-	-	-	-	-	-	-	-	-
17:00	-	-	-	-	-	-	-	-	-	-
WEST	JAN 15th	FEB 15th	MARC 15th	APRIL 16th	MAY15th	JUNE 15th	SEPT18th	OCT 16th	NOV15th	DEC 15th
07:00	-	-	-	-	-	-	-	-	-	-
08:00	-	-	-	-	-	-	-	-	-	-
09:00	-	-	-	-	-	-	-	-	-	-
10:00	-	-	-	-	-	-	-	-	-	-
11:00	-	-	-	-	-	-	-	-	-	-
12:00	-	-	-	-	-	-	-	-	-	-
13:00	-	-	-	-	-	-	-	-	-	-
14:00	-	-	-	-	-	-	-	-	-	-
15:00	-	-	-	-	-	-	-	-	-	-
16:00	-	-	-	-	¤	¤	-	-	-	-
17:00	-	-	-	-	¤	¤	-	-	-	-

DAYLIGHT AVAILABLITY AT THE PROPOSED CLASSROOM-ISTANBUL

EAST	JAN 15th	FEB 15th	MARC 15th	APRIL 16th	MAY15th	JUNE 15th	SEPT18th	OCT 16th	NOV15th	DEC 15th
07:00	-	-	¤	¤	-	-	-	-	-	-
08:00	-	-	¤	¤	-	-	-	¤	-	-
09:00	-	¤	¤	¤	-	-	-	¤	¤	-
10:00	¤	¤	¤	¤	-	-	-	¤	¤	-
11:00	¤	¤	¤	¤	-	-	-	¤	¤	-
12:00	-	¤	¤	¤	-	-	-	¤	-	-
13:00	-	-	-	¤	-	-	¤	¤	-	-
14:00	-	-	-	-	-	-	-	-	-	-
15:00	-	-	-	-	-	-	-	-	-	-
16:00	-	-	-	-	-	-	-	-	-	-
17:00	-	-	-	-	-	-	-	-	-	-
WEST	JAN 15th	FEB 15th	MARC 15th	APRIL 16th	MAY15th	JUNE 15th	SEPT18th	OCT 16th	NOV15th	DEC 15th
07:00	-	-	-	-	-	-	-	-	-	-
08:00	-	-	-	-	-	-	-	-	-	-
09:00	-	-	-	-	-	-	-	-	-	-
10:00	-	-	-	-	-	-	-	-	-	-
11:00	-	-	-	-	-	-	-	-	-	-
12:00	-	¤	¤	-	-	-	-	-	-	-
13:00	¤	¤	¤	¤	-	-	-	¤	¤	-
14:00	¤	¤	¤	¤	-	-	-	¤	¤	-
15:00	¤	¤	¤	¤	-	-	-	¤	¤	-
16:00	-	¤	¤	¤	-	-	-	¤	¤	-
17:00	-	¤	¤	¤	-	-	-	¤	-	-

Table 4a. *(Continued)*

DAYLIGHT AVAILABLITY AT THE EXISTING CLASSROOM-ISTANBUL

SOUTH	JAN 15th	FEB 15th	MARC 15th	APRIL 16th	MAY 15th	JUNE 15th	SEPT 18th	OCT 16th	NOV 15th	DEC 15th
07:00	-	-	-	-	-	-	-	-	-	-
08:00	-	-	-	-	-	-	-	-	-	-
09:00	-	-	-	-	-	-	-	-	-	-
10:00	-	-	-	-	-	-	-	-	-	-
11:00	-	-	-	-	-	-	-	-	-	-
12:00	-	-	-	-	-	-	-	-	-	-
13:00	-	-	-	-	-	-	-	-	-	-
14:00	-	-	-	-	-	-	-	-	-	-
15:00	-	-	-	-	-	-	-	-	-	-
16:00	-	-	-	-	-	-	-	-	-	-
17:00	-	-	-	-	-	-	-	-	-	-

NORTH	JAN 15th	FEB 15th	MARC 15th	APRIL 16th	MAY 15th	JUNE 15th	SEPT 18th	OCT 16th	NOV 15th	DEC 15th
07:00	-	-	-	-	-	-	-	-	-	-
08:00	-	-	-	-	-	-	-	-	-	-
09:00	-	-	-	-	-	-	-	-	-	-
10:00	-	-	-	-	-	-	-	-	-	-
11:00	-	-	-	-	-	-	-	-	-	-
12:00	-	-	-	-	-	-	-	-	-	-
13:00	-	-	-	-	-	-	-	-	-	-
14:00	-	-	-	-	-	-	-	-	-	-
15:00	-	-	-	-	-	-	-	-	-	-
16:00	-	-	-	-	-	-	-	-	-	-
17:00	-	-	-	-	-	-	-	-	-	-

DAYLIGHT AVAILABLITY AT THE PROPOSED CLASSROOM-ISTANBUL

SOUTH	JAN 15th	FEB 15th	MARC 15th	APRIL 16th	MAY 15th	JUNE 15th	SEPT 18th	OCT 16th	NOV 15th	DEC 15th
07:00	-	-	-	-	-	-	-	-	-	-
08:00	-	-	-	-	-	-	-	-	-	-
09:00	-	☼	☼	☼	-	-	-	-	☼	-
10:00	☼	☼	☼	☼	-	-	-	☼	☼	☼
11:00	☼	☼	☼	☼	-	-	☼	☼	☼	☼
12:00	☼	☼	☼	☼	-	-	☼	☼	☼	☼
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14:00	☼	☼	☼	☼	-	-	☼	☼	☼	☼
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NORTH	JAN 15th	FEB 15th	MARC 15th	APRIL 16th	MAY 15th	JUNE 15th	SEPT 18th	OCT 16th	NOV 15th	DEC 15th
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12:00	-	-	-	-	-	-	-	-	-	-
13:00	-	-	-	-	-	-	-	-	-	-
14:00	-	-	-	-	-	-	-	-	-	-
15:00	-	-	-	-	-	-	-	-	-	-
16:00	-	-	-	-	-	-	-	-	-	-
17:00	-	-	-	-	-	-	-	-	-	-

Table 4b. *Daylight availability at the investigated classroom module in Antalya.*

DAYLIGHT AVAILABILITY AT THE EXISTING CLASSROOM-ANTALYA

EAST	JAN 15th	FEB 15th	MARC 15th	APRIL 16th	MAY 15th	JUNE 15th	SEPT 18th	OCT 16th	NOV 15th	DEC 15th
07:00	-	-	-	-	-	☼	-	-	-	-
08:00	-	-	-	-	☼	☼	☼	-	-	-
09:00	-	☼	☼	☼	☼	☼	☼	☼	☼	☼
10:00	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
11:00	☼	☼	☼	☼	☼	☼	☼	☼	-	-
12:00	-	☼	☼	☼	☼	☼	☼	☼	-	-
13:00	-	-	-	☼	☼	☼	☼	-	-	-
14:00	-	-	-	☼	☼	☼	☼	-	-	-
15:00	-	-	-	☼	☼	☼	☼	-	-	-
16:00	-	-	-	☼	☼	☼	☼	-	-	-
17:00	-	-	-	-	☼	☼	-	-	-	-

WEST	JAN 15th	FEB 15th	MARC 15th	APRIL 16th	MAY 15th	JUNE 15th	SEPT 18th	OCT 16th	NOV 15th	DEC 15th
07:00	-	-	-	-	-	-	-	-	-	-
08:00	-	-	-	-	-	-	-	-	-	-
09:00	-	-	-	-	-	-	-	-	-	-
10:00	-	-	-	-	-	-	-	-	-	-
11:00	-	-	-	-	-	☼	-	-	-	-
12:00	-	-	-	☼	☼	☼	☼	-	-	-
13:00	-	-	-	☼	☼	☼	☼	-	-	-
14:00	-	-	☼	☼	☼	☼	☼	-	-	-
15:00	-	☼	☼	☼	☼	☼	☼	☼	☼	☼
16:00	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
17:00	☼	☼	☼	☼	☼	☼	☼	☼	-	-

DAYLIGHT AVAILABILITY AT THE PROPOSED CLASSROOM-ANTALYA

EAST	JAN 15th	FEB 15th	MARC 15th	APRIL 16th	MAY 15th	JUNE 15th	SEPT 18th	OCT 16th	NOV 15th	DEC 15th
07:00	-	-	-	-	-	☼	-	-	-	-
08:00	-	-	-	☼	☼	☼	☼	-	-	-
09:00	-	☼	☼	☼	☼	☼	☼	☼	-	-
10:00	☼	☼	☼	☼	☼	☼	☼	☼	☼	-
11:00	☼	☼	☼	☼	☼	☼	☼	☼	☼	-
12:00	-	☼	☼	☼	☼	☼	☼	☼	-	-
13:00	-	-	-	☼	☼	☼	☼	-	-	-
14:00	-	-	-	-	-	-	-	-	-	-
15:00	-	-	-	-	-	-	-	-	-	-
16:00	-	-	-	-	-	-	-	-	-	-
17:00	-	-	-	-	-	-	-	-	-	-

WEST	JAN 15th	FEB 15th	MARC 15th	APRIL 16th	MAY 15th	JUNE 15th	SEPT 18th	OCT 16th	NOV 15th	DEC 15th
07:00	-	-	-	-	-	-	-	-	-	-
08:00	-	-	-	-	-	-	-	-	-	-
09:00	-	-	-	-	-	-	-	-	-	-
10:00	-	-	-	-	-	-	-	-	-	-
11:00	-	-	-	-	-	-	-	-	-	-
12:00	-	-	-	-	-	-	-	-	-	-
13:00	-	-	-	-	-	-	-	-	-	-
14:00	-	-	-	☼	-	-	-	-	-	-
15:00	☼	☼	☼	☼	-	-	-	-	-	☼
16:00	☼	☼	☼	☼	-	-	-	-	-	☼
17:00	☼	☼	☼	☼	-	-	-	-	-	-

Table 4b. *(Continued)*

DAYLIGHT AVAILABILITY AT THE EXISTING CLASSROOM-ANTALYA

SOUTH	JAN 15th	FEB 15th	MARC 15th	APRIL 16th	MAY 15th	JUNE 15th	SEPT18th	OCT 16th	NOV15th	DEC 15th
07:00	-	-	-	-	-	-	-	-	-	-
08:00	-	-	-	-	-	-	-	-	-	-
09:00	☼	☼	☼	☼	-	-	-	-	☼	☼
10:00	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
11:00	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
12:00	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
13:00	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
14:00	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
15:00	☼	☼	☼	☼	☼	☼	☼	☼	-	-
16:00	-	-	-	☼	☼	☼	-	-	-	-
17:00	-	-	-	-	☼	☼	-	-	-	-

NORTH	JAN 15th	FEB 15th	MARC 15th	APRIL 16th	MAY 15th	JUNE 15th	SEPT18th	OCT 16th	NOV15th	DEC 15th
07:00	-	-	-	-	-	-	-	-	-	-
08:00	-	-	-	-	-	-	-	-	-	-
09:00	-	-	-	-	-	☼	-	-	☼	-
10:00	-	-	-	☼	☼	☼	☼	☼	☼	-
11:00	-	-	-	☼	☼	☼	☼	☼	☼	-
12:00	-	-	-	☼	☼	☼	☼	☼	☼	☼
13:00	-	-	-	☼	☼	☼	☼	☼	☼	☼
14:00	-	-	-	☼	☼	☼	☼	☼	☼	☼
15:00	-	-	-	☼	☼	☼	☼	☼	-	-
16:00	-	-	-	-	-	☼	-	-	-	-
17:00	-	-	-	-	-	-	-	-	-	-

DAYLIGHT AVAILABILITY AT THE PROPOSED CLASSROOM-ANTALYA

SOUTH	JAN 15th	FEB 15th	MARC 15th	APRIL 16th	MAY 15th	JUNE 15th	SEPT18th	OCT 16th	NOV15th	DEC 15th
07:00	-	-	-	-	-	-	-	-	-	-
08:00	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
09:00	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
10:00	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
11:00	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
12:00	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
13:00	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
14:00	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
15:00	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
16:00	☼	☼	☼	☼	☼	☼	☼	☼	☼	☼
17:00	-	-	-	☼	☼	☼	☼	☼	-	-

NORTH	JAN 15th	FEB 15th	MARC 15th	APRIL 16th	MAY 15th	JUNE 15th	SEPT18th	OCT 16th	NOV15th	DEC 15th
07:00	-	-	-	-	☼	☼	-	-	-	-
08:00	-	-	-	☼	☼	☼	☼	-	-	-
09:00	-	-	☼	☼	☼	☼	☼	-	-	-
10:00	-	☼	☼	☼	☼	☼	☼	☼	☼	-
11:00	-	☼	☼	☼	☼	☼	☼	☼	☼	-
12:00	-	☼	☼	☼	☼	☼	☼	☼	☼	-
13:00	-	☼	☼	☼	☼	☼	☼	☼	☼	-
14:00	-	☼	☼	☼	☼	☼	☼	☼	☼	-
15:00	-	☼	☼	☼	☼	☼	☼	☼	-	-
16:00	-	-	☼	☼	☼	☼	☼	☼	-	-
17:00	-	-	-	☼	☼	☼	☼	-	-	-

☼ *: Daylight availability provides the required illumination*
\- *: Daylight availability is insufficient*

Artificial lighting system of the existing classroom module

In Turkey, tubular fluorescent lamps are the most frequently used light sources with parabolic louvers at the “Elementary School Prototype Projects”. The lighting energy consumption of the classroom was predicted basing on the daylight availability during the working hours. As there is no automatic control system in the existing classroom module, it was assumed that all lamps are turned on when the illuminance supplied with daylight is below 300 lx on the working plane. Therefore, energy consumption was predicted according to the working hours during which daylight illuminance supplied with daylight on the working plane is below 300 lx. The monthly and annual energy consumption of the classroom module was calculated for the occupation time during the whole academic year.

Artificial lighting system of the proposed classroom module

A new artificial lighting system was proposed for the classroom module, which covers automatic control system. Automatic control system integrates artificial light with daylight. The lighting system was designed by using Calculux Indoor 5.0 Program (Calculux Indoor 5.0.b). The lighting system is supplied by 9 luminaires (TPS 670/128 MD) equipped with TL’5 fluorescent lamps of 28 Watt. Luxsense (Luminaire based lighting sensor for TL’5) is a light sensing device, meant to be integrated into the down-lighting luminaire, thus adding a regulating function in combination with a regulating ballast (electronic-dim ballast) (TRIOS, Luxsense, 2006). When all lamps are operated, the energy consumption for each of the lamp is 33W (28W lamp, 5W electronic ballast consumption). When daylight illuminance is below 300 lx, the system provides the lacking amount of illumination to reach at the required level.

Results and discussion

In the present study, a more energy efficient lighting system is proposed for the typical elementary school projects, while improving the existing visual and climatic comfort conditions. To provide energy conscious design, a daylight responsive artificial lighting system with a proper solar control system is developed to provide both visual comfort conditions and energy efficiency while taking into account heating and cooling loads. In the study, the monthly and the annual lighting energy requirements of the classroom module for the two climate types; Istanbul and Antalya, were calculated according to the occupation time during the whole academic year. The comparison of annual lighting energy requirements according to the orientation for the existing and the proposed facades in Istanbul and Antalya are given in Table 5.

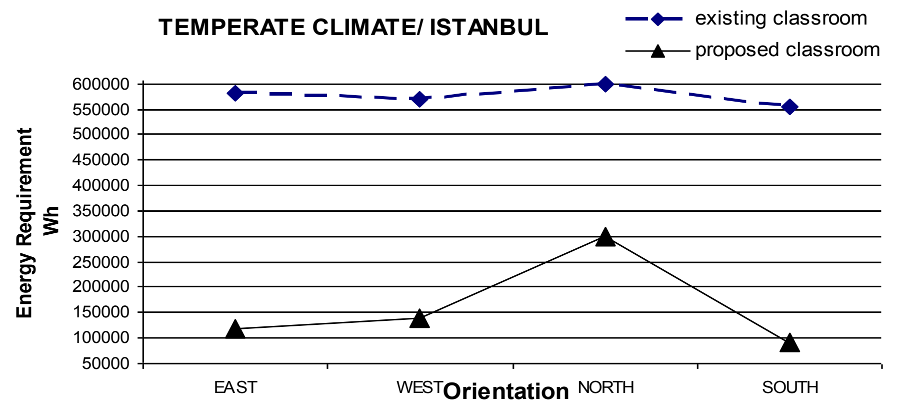
Table 5. *Comparison of annual energy requirement-Wh.*

Region	Orientation	Existing Classroom Module Annual Energy Requirement Wh	Proposed Classroom Module Annual Energy Requirement Wh
Istanbul/ Temperate Climate	East	583011	115110
	West	573210	139328
	North	604395	298255
	South	554499	91895
Antalya/ Hot Climate	East	310365	114673
	West	363825	225087
	North	518265	57290
	South	237006	22634

As it is seen in Table 5, artificial lighting energy saving for the proposed classroom module due to the orientation is achieved at the following ratios; 80% east, 76% west, 51% north, 83% south orientations in Istanbul, in temperate climate region. Artificial lighting energy saving for the proposed classroom module due to the orientation is achieved at the following ratios; 63% east, 38% west, 89% north, 90% south orientations in Antalya in hot climate region.

Viewed from the perspective of lighting energy loads, it can be argued that, the energy requirements of the proposed systems are more economical as illustrated in Figure 5. When the existing and proposed systems are compared from the visual comfort conditions point of view, the absence of glare and homogenous distribution of light on the working plane are among the positive aspects of the proposed facade configurations. In case movable shading elements are integrated to the facade for the east, west and south orientations windows are shaded during the shading period. Also the climate type and the orientation gains importance for the amount of annual energy consumption. In the north orientation, as the transparency ratio is increased, daylight levels achieved on the working plane also increase. This leads to diminishing of the artificial lighting energy consumption at the proposed classroom module.

It is also suggested to operate shading elements automatically depending on the solar incidence on the facade, better results can be obtained in terms of both visual and climatic comfort conditions and lighting, heating-cooling loads.



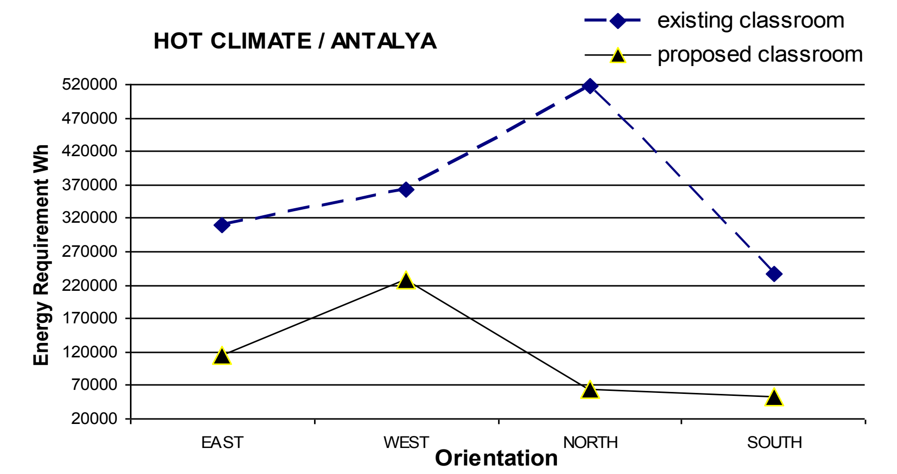


Figure 5. *Annual energy requirements for the existing and the proposed facades in Istanbul and in Antalya.*

Finally, it can be said that daylight illumination can be maximized in the classroom module with a proper facade design taking into consideration the climatic characteristics. In addition to the proper facade design, the artificial lighting system is designed as a complement to daylight, luminaries are controlled according to the daylight availability, annual energy consumption is decreased, visual comfort conditions are improved.

Conclusion

In Turkey, prototype school projects are implemented by the Ministry of Public Works and Settlement. Typical project implementation entails a design process which is independent of location and thus can be repeated at multiple sites in various forms. Natural, physical and structural characteristics of the specific location, which constitute the data for the project's design process, are ignored. As a result of this application, energy consumption of the system is too high, visual and climatic comfort conditions are overestimated. The results of the study show that orientation-dependant facade design plays an important role in energy efficiency of buildings. Future goals include incorporating this study with cold climate type and also to generalize the results for the typical projects in Turkey. As the solar control principles depend on the sky conditions and location (latitude and longitude) proposals in the study can be offered for similar climate types. In the study, high reflective, light coloured, matte surfaced aluminium shading devices are selected. Taking the advance of technology, different material types can be analyzed and the study can be enlarged.

The study reports to minimize artificial lighting energy loads while improving visual and climatic comfort conditions by means of facade design. This argument is an important issue at architectural ecological design. It is hoped that this paper will provide a base to underline the importance of designing energy-conscious school buildings.

[1] *Corresponding author*

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Sıcak ve ılımlı iklim bölgelerindeki okullarda günışığı analizi ve aydınlatma enerji yönetimi

Doğal kaynakların kirlenmesi sonucunda çevresel sorunlara neden olan ve biyolojik çeşitliliği azaltarak ekosistemdeki dengeyi bozan ve insan sağlığını tehdit eden faaliyetler, özellikle 19. yy endüstrileşme hareketi ile hız kazanmıştır. Kullanılan enerji kaynaklarının tükenecek olması ve çevreye olan olumsuz etkileri, yapma çevre oluşumuna ilişkin kararların tüm süreçler genelinde daha dikkatli alınmasını gerekli kılmaktadır. Yapma çevreyi oluşturan binalar, çevresel etkileri bakımından incelendiğinde ham madde kullanımı ve enerji tüketimi bakımından, dünya genelinde yaklaşık %40 etkiye sahiptir. Uluslararası Enerji Ajansı (International Energy Agency-IEA)'nın 2005 yılı verilerine göre dünya genelinde binaların neden olduğu enerji tüketiminin, yıllık 2500 milyon ton petrole denk geldiği ifade edilmektedir. Ayrıca tüm dünyada, sera etkisi oluşturan gaz emisyonlarının 1/3 'i binalar tarafından atmosfere salınmaktadır. Tüm bu veriler göz önünde bulundurulduğunda, mimarlığın üstlendiği rol ve etkilerinden dolayı çevreye karşı sorumluluğunun oldukça fazla olduğu görülmektedir. Bu açıdan bakıldığında, mimaride enerji etkin tasarım kavramı önem kazanmaktadır. Bu tasarım anlayışında hacimde konfor koşullarından ödün vermeksizin, verimlilik arttırılırken binaların çevreye olan olumsuz etkileri de azaltılmaya çalışılmaktadır.

Enerji etkin tasarımda güneş ışığının tasarıma veri teşkil etmesi önemlidir. Doğal enerji kaynaklarından biri olan güneş ışığının oluşturduğu günışığı aydınlatması; hacmin bulunduğu yerin enlem ve boylamına, atmosferin yapısına ve zamana göre değişim göstermektedir. Enerji etkin tasarımda; doğal aydınlatma düzenlerinin; saydamlık oranı, pencere türü gibi kabuk bileşenleri ile günışığı kontrol sistemlerinin doğru seçimi, hacmin yönlendiriliş durumu gibi parametreler kontrol altında tutularak gün boyu çalışılan hacimlerde yapma aydınlatma enerji tüketimini azaltmak ve kullanıcıların dış ortamla ilişkisini sağlayarak psikolojik ihtiyaçlarını gidermek mümkündür. Günışığı kontrol sistemleri, hacme girecek direkt güneş ışınımını kontrol altında tutarak mekanda gerçekleşmesi istenen görsel konfor koşullarının yanı sıra, iklimsel konfor koşullarının sağlanmasında da önemli bir strateji olarak kabul edilmektedir.

Genç nesillerin hayata hazırlanmasında okul önemli bir rol üstlenmektedir. Gençlerin bilgi, beceri ve güven kazanarak geleceklerini şekillendiren okul yaşamlarında akademik başarı, yüksek performans ve psikolojik açıdan memnuniyet ve mutluluk hissinin oluşmasında ise aydınlatmanın etkisi büyüktür. Başarılı bir aydınlatma tasarımı öğrenmeyi destekleyerek genç beyinlerin konuya odaklanmalarına, dikkatlerini toplamaya, çalışma ortamının rahat ve öğrencilerin daha katılımcı olmasına olanak tanır.

Dersliklerde doğru bir aydınlatma tasarımı, öncelikle günışığı kullanımını etkinleştirmeyi, günışığı dinamiklerini hacme getirerek, öğrencilere en iyi öğrenme ortamını sağlar. Bununla birlikte amaca uygun olarak doğru seçilmiş bir aydınlatma otomasyonu ile enerji yönetimi açısından etkili, öğrenme ortamını çevreci bakış açısıyla optimize eden bir tasarım anlayışı geliştirilebilir. Bu doğrultuda Avrupa Birliği'nin geliştirmiş olduğu direktiflerden biri olan EuP direktifi ile 2020 yılına kadar aydınlatma alanında toplam enerji tüketimi %20 oranında azaltılmaya çalışılarak aydınlatma ürünlerinin çevreye olumsuz etkilerinin azaltılması hedeflenmektedir. Bu kapsamda alınan tedbirlere göre; enerji etkinliği düşük lambaların kullanımdan kaldırılması için izin verilen süreler; enkandesan ve T12 lambalar için en geç 2011 yılı sonu, TLD standart lambalar için 2009 yılı sonu, civa buharlı lambalar için 2014 yılı olarak belirlenmiştir.

Bununla birlikte aydınlatma enerji yönetimi konusunda yapılan araştırmalardan, 2009 yılında Almanya Hamburg'da gerçekleştirilen deneysel bir çalışmanın sonuçları, aydınlatmada enerji yönetiminin tasarruf açısında ne kadar önemli olduğunu bir kez daha ortaya koymaktadır. Farklı derslik hacimlerinde yaşları 8 ile 16 arasında değişen toplam 166 öğrenci ve 18 öğretmenden oluşan bir denek grubu üzerinde deneysel bir çalışma yapılmıştır. Günışığına duyarlı bir aydınlatma otomasyonuna sahip ve aydınlatma açısından enerji etkinliği daha yüksek aydınlatma araçları ile düşük renk sıcaklığına sahip ışık kaynaklarından oluşan bir aydınlatma sisteminin; farklı yaş grubundan bütün öğrencilerin çalışma performansı üzerindeki etkileri incelenmiştir. Çalışmanın sonucunda aydınlatma tasarımının öğrencilerin akademik başarılarını arttırdığı, dikkat sürelerini ve konsantrasyonlarını uzattığı ve davranışlarını olumlu yönde önemli ölçüde geliştirdiği görülmüştür (Schulte-Marktwork, v.d. 2009). Okullarda enerji kullanımının %70'i aydınlatma kaynaklı olup, yapılan bu deneysel çalışma ile aydınlatma yükünü dersliklerde doğru aydınlatma aracı seçimi ile %30, günışığına duyarlı otomasyon sistemi seçimi ile %50 'lere varan oranlarda azaltmanın mümkün olduğu görülmüştür.

Okulların, enerji etkin tasarım ilkelerine göre iklim ve aydınlatma kontrolü açılarından optimum performans gösteren pasif sistemler olarak tasarlanmaları ile aktif sistemlerin enerji yükü minimize edilerek enerji kaynaklarının daha bilinçli kullanımı sağlanacaktır. Bununla birlikte öğrenci ve öğretmenlerin iklimsel ve görsel konfor durumlarının sağlanması ile performansları artacak, bulundukları ortamdan hoşnut olmaları sağlanacaktır.

Ülkemizde ise ilköğretim okulları tasarımında Bayındırlık ve İskan Bakanlığı tarafından tip proje uygulaması yapılmaktadır. Bu uygulama konfor koşulları ve enerji yönetimi açısından pek çok eksiklikler içermektedir. Tip proje uygulaması, projelerin farklı karakter ve iklime sahip pek çok yerde tekrar edilebilmesi açısından yerleşmeden bağımsız bir tasarım sürecini içermektedir. Oysa ki projenin tasarım sürecine veri teşkil eden; yerleşmeye ait doğal, fiziksel ve yapısal özelliklerin tasarıma yön vermek üzere kullanılması enerji etkin tasarımın temel prensibini oluşturmaktadır. Gün boyu kullanılan binalar olmaları sebebiyle, ilköğretim okullarının tasarımında enerji etkin tasarım ilkelerinin değerlendirilmesi ve kullanılması büyük öneme sahiptir.

Bu çalışmada, farklı iklim bölgelerinde yer alan ilköğretim dersliklerinin enerji etkin tasarım bakış açısıyla değerlendirilmesi amaçlanmaktadır. Bu nedenle, farklı iklim bölgelerinde yer alan dersliklerde iklimsel ve görsel konfor koşullarının sağlanması ve yapma aydınlatma enerji yüklerinin minimize edilmesinde, yönlere göre uygun kabuk ve gölgeleme araçlarının belirlenmesi yani cephe tasarımı önerisi geliştirilmektedir.

Çalışmada ele alınan derslik hacminin sıcak ve ılımlı iklim bölgelerinde yer aldığı kabul edilmiştir. Sıcak iklim bölgesi için Antalya, Ilımlı İklim bölgesi için İstanbul pilot şehir seçilmiştir. Bayındırlık ve İskan Bakanlığı'nın ülkemiz genelinde uygulamış olduğu tip ilköğretim okulu projelerinden alınan, boyutları ve özellikleri tanımlanmış ve farklı yönlere baktığı kabul edilen derslik hacminde, gün boyunca aydınlatmanın fizyolojik amacını yerine getirmek üzere, görsel konfor ve enerji korunumu açılarından en uygun kabuk seçenekleri analiz edilerek, dersliklerdeki yapma aydınlatma enerji ihtiyaçlarının bir karşılaştırması yapılmıştır. Aydınlatma enerji tüketimlerinin karşılaştırması, Bakanlığın mevcut uygulaması ile öneri derslik hacimleri arasında yapılmaktadır. Araştırmada, farklı iklim bölgelerinde yer alan dersliklerde elde edilen günışığı aydınlık düzeylerinin hesaplanmasında bilgisayar tabanlı günışığı simulasyon aracı Radiance 2.0 Beta programı kullanılmıştır.

Çalışmanın sonuçları, iklim bölgelerinin özelliklerine ve yöne göre değişen cephe tasarımının, binalarda enerji etkin tasarım açısından önemli olduğunu, yapma aydınlatma enerji tüketimini büyük ölçüde azalttığını göstermektedir. Bu kapsamda yapılması planlanan bir başka çalışma ile soğuk iklim bölgesi verilerinin de dikkate alınarak araştırmaya katılması, tüm bu veriler ile Türkiye'de farklı iklim bölgeleri ve farklı yönlere göre planlanan tip projeler için genelleme yapılabilecek sonuçların elde edilmesine çalışılacaktır. Hacimde konfor koşulları sağlanırken aynı zamanda yapma aydınlatma enerji yüklerinin azaltılması yönünde gerçekleştirilen bu araştırma ile okul binaları tasarımında enerji etkin tasarım ilkelerinin önemi vurgulanmakta, bu yönde yapılacak başka çalışmalara katkıda bulunulması umulmaktadır.