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Investigation of Lighting Performance and Improvement of Efficiency in a Designated Area of an Active Educational Building

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Anahtar Kelimeler

Aydınlatma
Aydınlatma Performansı
Eğitim Binası
Enerji Verimliliği
Fotometri

Graphical/Tabular Abstract (Grafik Özet)

In this study, the lighting devices used in a selected classroom at the Central Classroom Building of Hakkari University Zeynelbey Campus were examined, and photometric measurements were conducted in this area. The classroom was modeled using DIALux lighting design software, and a more efficient and economical lighting model was proposed by utilizing lighting devices with different power ratings and features for these spaces. / Bu çalışmada, Hakkari Üniversitesi Zeynelbey yerleşkesindeki Merkez Derslik binasında seçilmiş bir sınıfta kullanılan aydınlatma cihazları incelenmiş ve bu alanda fotometrik ölçümler yapılmıştır. Sınıf DIALux aydınlatma tasarım yazılımı kullanılarak modellenmiş ve bu alanlar için farklı güç ve özelliklere sahip aydınlatma cihazları kullanılarak daha verimli ve ekonomik bir aydınlatma modeli önerilmiştir.

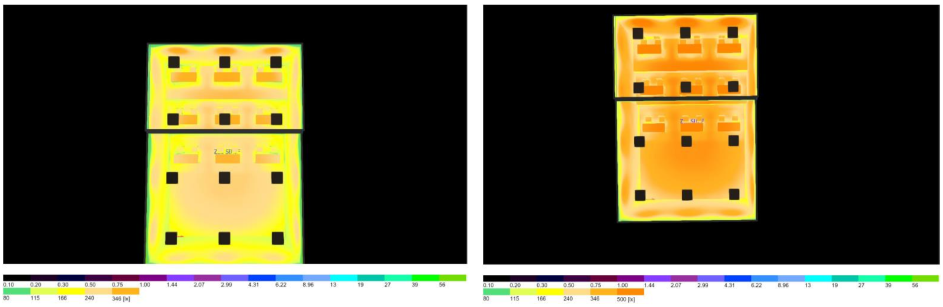

Figure A: *Illuminance levels of the classroom modeled in the DIALux /* ***Şekil A:*** *DIALux'te modellenen sınıfın aydınlatma seviyeleri*

Highlights (Önemli noktalar)

- *Ensuring the selection of appropriate lighting systems to reduce energy consumption. / Enerji sarfiyatını azaltmak için uygun aydınlatma sistemlerinin seçilmesinin sağlanması.*
- *Providing recommendations for determining the usage patterns of lighting devices. / Aydınlatma aygıtlarının kullanım şekillerinin belirlenmesine yönelik öneriler sunulması.*
- *Ensuring the identification of the most efficient lighting conditions through photometric measurements by using LED panels with different power ratings and features. / Fotometrik ölçümler yaparak farklı güç ve özelliklerde LED panel kullanılması ile en verimli aydınlanma durumunun ortaya çıkarılmasının sağlanması.*

Aim (Amaç): *Conducting photometric measurements under the existing luminaires in a classroom, determining the most efficient lighting scenario using LED panel luminaires with different power ratings and features, and evaluating the lighting performance. / Bir sınıfta mevcut armatür altında fotometrik ölçümler yapılması, farklı güç ve özelliklerdeki LED panel armatür kullanılarak en verimli aydınlatma senaryosunun belirlenmesi ve aydınlatma performansının değerlendirilmesi.*

Originality (Özgünlük): *This study offers a new contribution to energy efficiency and the economy through next-generation LED technologies, as opposed to traditional lighting approaches used in educational institutions. / Bu çalışma, eğitim kurumlarında kullanılan geleneksel aydınlatma yaklaşımlarının aksine yeni nesil LED teknolojileri ile enerji verimliliği ve ekonomiye yeni bir katkı sunmaktadır.*

Results (Bulgular): *The 30 W LED panel, which exceeds standard lighting levels, provides a more uniform distribution of lighting and luminous intensity. Therefore, it is appropriate to replace the existing luminaires with 30 W LED panel luminaires. / Standart aydınlatma düzeylerini aşan 30 W LED panelin aydınlatma ve ışık şiddeti dağılımı daha homojendir. Bu nedenle mevcut armatürlerin 30 W LED panel armatür ile değiştirilmesi uygundur.*

Conclusion (Sonuç): *The most suitable lighting model for the specified area is the 30 W LED panel luminaire. It has been concluded that this device is more appropriate and a more viable investment compared to other LED panels. / Belirtilen alan için en uygun aydınlatma modeli 30 W LED panel armatür'dür. Bu aygıtın diğer LED panellere göre daha uygun ve yatırım yapılabilir olduğu sonucuna varılmıştır.*

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Abstract

Due to the inefficient use of daylight in many areas, the demand for artificial light sources, which have a history of approximately 200 years, has increased. This increase has particularly highlighted the need to investigate the energy quality, savings and efficiency of lighting systems in modern times. In this study, the lighting devices used in a selected classroom within the Central Classroom building at Hakkari University's Zeynelbey campus were examined. Photometric measurements were conducted under different seasonal conditions (winter and summer) in this area, including scenarios with natural, artificial and combined lighting. The obtained results were compared and evaluated against current standards. Additionally, the measured classroom was modeled using the DIALux lighting design software and a more efficient and economical lighting model was proposed using lighting devices with different power and characteristics for these areas. Based on the findings of this study, recommendations were made for selecting appropriate lighting systems and determining the usage patterns of lighting devices to improve working conditions and further reduce energy consumption with the existing lighting devices.

Faal Bir Eğitim Binasında Belirlenmiş Bir Alanda Aydınlatma Performansının İncelenmesi ve Verimliliğinin İyileştirilmesi

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Öz

Birçok alanda gün ışığının verimli kullanılamaması nedeniyle yaklaşık 200 yıllık bir geçmişe sahip yapay ışık kaynaklarına olan talep artmıştır. Bu artış özellikle günümüzde aydınlatma sistemlerinde enerji kalitesi, tasarrufu ve verimliliğinin incelenmesi durumunu ortaya çıkarmaktadır. Bu çalışmada, Hakkâri Üniversitesi Zeynelbey yerleşkesinde yer alan Merkezi derslikler binasında belirlenen sınıf'ta kullanılan aydınlatma aygıtları incelenmiş ve bu alanlardaki farklı mevsimsel koşullarda (kış ve yaz) doğal, yapay ve her ikisinin bulunduğu durumlarda fotometrik ölçümler gerçekleştirilmiştir. Elde edilen sonuçlar mevcut standartlar ile karşılaştırılmış ve değerlendirilmiştir. Ayrıca ölçüm yapılan sınıf, DIALux aydınlatma tasarım programı kullanılarak modellenmiş, bu alanlar için farklı güç ve özelliklerde aydınlatma aygıtları ile daha verimli ve tasarruflu bir aydınlatma modeli önerilmiştir. Bu çalışmadan elde edilen bulgulara göre mevcut aydınlatma aygıtları kullanılarak çalışma koşullarını arttırmak, enerji sarfiyatını daha da azaltmak için uygun aydınlatma sistemlerinin seçilmesi ve aydınlatma aygıtlarının kullanım şekillerinin belirlenmesine yönelik öneriler sunulmuştur.

1. INTRODUCTION (GİRİŞ)

Due to irregular budgeting and project planning, necessary investments in new generation lighting technologies cannot be made across both the public and private sectors, including educational buildings and the adoption of control technologies progresses at a rather slow pace despite sufficient daylight throughout the year. However, the importance of lighting systems and their contribution to energy efficiency are becoming increasingly significant in all areas. The design and performance of lighting systems in educational buildings enhance the efficiency of work in that area, creating a more comfortable environment. In this context, it is essential to conduct necessary measurements and detailed analyses on the lighting systems within educational buildings. This study aims to contribute to energy efficiency efforts in our country by researching and analyzing the performance of a lighting system in a classroom with the highest occupancy at Hakkari University.

Lighting has been identified as one of the most cost-effective targets for increasing energy efficiency in buildings [1]. The topic of lighting performance and

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its associated energy savings is a vast area of research and this subject has been examined from various perspectives in the literature. Numerous studies have been conducted by researchers over the years to minimize energy consumption in public institutions, particularly in educational institutions, including in our country. Based on the results of these studies, new energy-saving methods have been identified and improvement methods have been implemented [2-5]. In this context, studies on energy efficiency in educational buildings are widely available in the literature. However, since the project will be implemented in a selected area within the Central Classroom building at Hakkari University’s Zeynelbey campus, the literature on lighting and energy efficiency improvement in our country has been reviewed.

Uyan and Yener have explored topics related to the assessment of the need for renewal, which is the first stage of a project approach that should be developed for the renewal process of existing lighting systems [6]. Çelik and Ünver have provided several recommendations on the procedures that should be conducted before undertaking improvement (retrofit) work on the lighting arrangements in school buildings [7]. Canol et al., conducted a techno-economic analysis of LED tube retrofit applications in a real office environment modeled in the DIALux program and performed benefit–cost analyses [8]. Yılmaz and Sungur, in their study conducted in a 16-classroom educational building in Bozkır district of Konya, determined the usage durations and power of lighting devices and subsequently calculated the amount of energy savings when replacing the existing lighting liminaire with LED lamps [9]. Aydoğdu, using an energy savings analysis calculation method developed as part of a doctoral study at Istanbul Technical University, calculated the electricity savings obtained by applying new technology LED lighting luminaire to an existing building [10]. In his thesis study, Usal compared a commonly used office lighting design utilizing LED luminaire whose usage has become widespread in recent times and has yielded effective results in many areas with an improved version of this design [11].

In their study, Önak and Yıldıran measured the illumination level and distribution in selected workshops within the Architecture Faculty building at Kocaeli University under the existing lighting conditions, modeled the environment using the DIALux program and compared the results with standard values [12]. Demir et al., in their study conducted at the Engineering Faculty building of Yalova University, discussed the importance of energy savings and efficiency in lighting and investigated the contributions of changes in lighting systems (such as replacing luminaire with LED) to energy savings [13]. Similarly, Kırbaş, in research on the lighting systems of the Engineering and Architecture Faculty building at Burdur Mehmet Akif Ersoy University (MAKÜ), determined that more than 8.5 million TL could be saved by using LED lamps instead of fluorescent lamps [14]. Bayram et al., using a luxmeter, measured illumination levels under natural lighting, artificial lighting and a combination of both in the Civil Engineering building and its extensions at Ege University’s campus and evaluated the results according to the TS EN 12464-1 Standard [15]. Korkmaz and Samancı examined the current state of energy, including lighting systems, in the Faculty of Engineering and Natural Sciences building at Konya Technical University and investigated the potential for energy efficiency [16]. Ateş et al., conducted measurements throughout the year and investigated energy-saving performance using computer-based energy modeling at the Köprübaşı Vocational School building of Manisa Celal Bayar University [17]. Selimli et al., measured the illumination levels in ten classrooms of another educational institution, determining that the lighting levels in these areas exceeded the standard level of 300 lux. Despite the illumination level being above the standard values, they found that further energy savings could be achieved in the same environment by using LED luminaire [18].

This study aims to conduct photometric measurements under the existing luminaire in a selected classroom/auditorium within the Central Classroom building at Hakkari University's Zeynelbey campus a newly developing campus area with high human density and to identify the most efficient lighting scenario by using LED panel luminaire of different power and characteristics and to evaluate the lighting performance. This will enable the identification of deficiencies in the current lighting systems and facilitate the early and rapid implementation of more efficient lighting solutions. Additionally, based on the results obtained, recommendations for improvement methods will be provided within the framework of the regulations and directives that have come into effect in our country, with the aim of enhancing lighting performance and, consequently, energy efficiency. In this context, in accordance with Presidential Decree No. 2023/15 dated 04/11/2023, which aims to achieve a minimum of 30% energy savings in public buildings by the end of 2030, the study intends to conduct lighting measurements in designated areas of the Central Classroom building at Hakkari University's Zeynelbey campus and analyze the lighting performance when using lighting devices that are more suitable for modern technology.

The remainder of the study is organized as follows. Section 2, provides information on lighting and lighting technology. In Section 3, the lighting system of the building and area under study is examined in detail and the lighting design planning is carried out. Additionally, the details of the study are explained in this section. In Section 4, the lighting designs are presented and the results obtained are evaluated and discussed. Finally, the conclusions drawn from the study are presented in Section 5.

2. OVERVIEW OF LIGHTING AND LIGHTING DEVICES (AYDINLATMA ve AYDINLATMA AYGITLARINA GENEL BAKIŞ)

Lighting is defined by the CIE, an authoritative organization established in 1913, as the application of light to objects, surroundings and small or large areas to make them visible [19]. The concept of lighting, which began with the discovery of coal gas in 1753 and the invention of the electric battery in 1796, has evolved from the development of the first incandescent lamp in 1841, to the creation of fluorescent lighting in 1930 and to the modern LED technology. The historical development of components used in lighting systems is illustrated in Figure 1 [20].

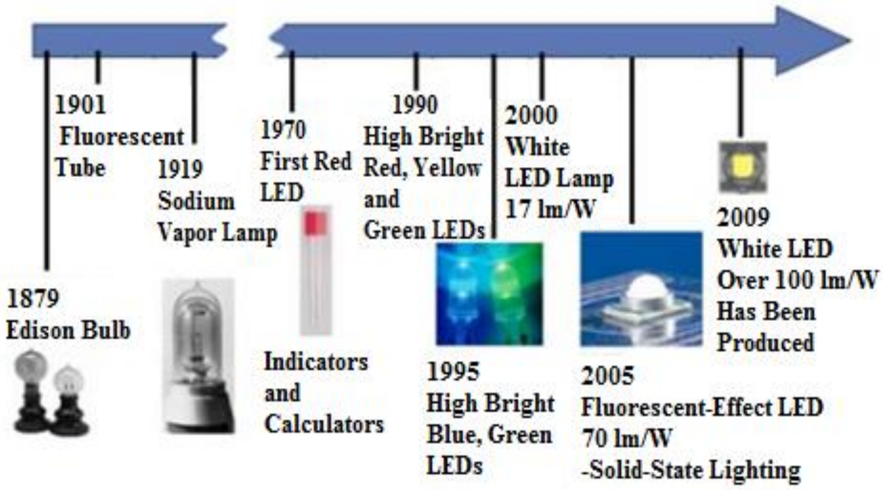


Figure 1. Historical development of electric lighting components (Elektrik aydınlatma elemanlarının tarihsel gelişimi)

Various lighting elements are used to provide artificial lighting in almost every field, both indoors and outdoors. The first lighting element, known as the Edison bulb, is the incandescent filament lamp. In this lamp, the current passing through a thin metal wire heats the filament to a glowing state, causing the metal to emit light. Due to excessive power consumption, heating and low efficiency, these lamps are not widely preferred today. Instead, halogen lamps, which have a longer lifespan and contain halogen gas are favored. However, these lamps are suitable for use in areas where electrical power is not subject to interruptions. Additionally, discharge lamps, which produce light by ionizing gases or mercury/sodium vapor contained in tube-shaped lamps, have been widely used both in the past and present, especially for outdoor lighting. Until the development of LED technology, the lighting needs of almost all buildings were met by mercury vapor lamps, which are based on the principle of producing light through fluorescent powders activated by ultraviolet (UV) radiation generated by mercury discharge. While they have advantages such as not overheating, having an economic lifespan and providing more light, they also have disadvantages such as not providing immediate light and being costly. These lamps are still used in many homes, workplaces, public institutions and private sector buildings today [20-22].

A transformation period is rapidly beginning today, where both indoor and outdoor lighting is being upgraded with LED technology due to its long lifespan [23]. LEDs (Light Emitting Diodes) are a type of lighting that has become well-known for its energy efficiency, long life, lighting effectiveness and low maintenance costs [24]. LEDs are cost-effective and do not contain harmful heavy metals [25, 26]. With advancing technology, the latest generation of LED lamps consumes 16 times less energy compared to incandescent lamps and has efficiency rates exceeding 50% compared to traditional lamps, with LED lamp efficiency continually improving [27].

3.MATERIALS AND METHODS (MATERYAL VE METOD)

In educational buildings, ensuring visual comfort in spaces where instruction takes place is of great importance. One of the most crucial conditions for creating visual comfort is lighting. In university buildings with various types of spaces such as classrooms and laboratories, providing an appropriate level of illumination according to the current situation enables individuals in the environment to perform their activities effectively without experiencing fatigue or problems with visual perception and selection. Moreover, excessive lighting not only leads to health issues but also results in increased energy consumption, causing deficiencies in energy savings. Overcoming this issue involves maintaining lighting within standard value thresholds and replacing outdated lighting luminaire with newer ones. This section provides a detailed explanation of the study's framework and modeling work.

3.1. Study Area and Characteristics (Çalışma Alanı ve Özellikleri)

The need for illumination is a significant factor affecting performance, comfort and especially safety in various living environments. However, this need increases energy consumption and highlights the necessity for energy savings. Due to the growing population density worldwide, energy use and demand are rising daily. In our country, the amount of electricity used for lighting accounts for approximately 20% of the total electricity consumption. Considering this, it is assessed that savings in lighting systems, especially in public buildings, could significantly contribute to the national economy.

The study site is the Central Classroom building located within the Hakkari University Zeynelbey campus, which is frequented by a large number of students, academic staff and other employees across various faculties and schools. This building includes academic and administrative staff offices, conference rooms, workshops, a computer laboratory, auditoriums and classrooms. Consequently, the Central Classroom building is particularly busy during weekdays, which increases energy consumption. Energy consumption is significantly high within the building's total energy usage. Therefore, it is necessary to conduct lighting measurements, performance evaluations and analysis for improving lighting efficiency to reduce energy consumption in the Central Classroom building. The Central Classroom building is a large structure with open sides and is the most frequently used building by all university units. Figure 2 shows the location of the Central Classroom building within the campus and the classroom (Z12).

Figure 2. The central classroom building and the classroom where the measurements were made (Merkezi derslikler binası ve ölçüm yapılan sınıf)

The modeled classroom has a floor area of 92.35 m², with dimensions of 11.3 m. in length, 8.3 m in width and 4.3 m in height. It features a beam partition in the center and a single facade with six windows. The classroom includes one instructor's desk and a total of 21 student desks fixed to the floor. The desks are arranged in three rows, with an approximate spacing of 1 m. between each row. The height of both the instructor's desk and the student desks from the floor is 0.9 m.

3.2. Lighting Design Planning (Aydınlatma Tasarımı Planlaması)

In educational institutions, particularly in classrooms, lecture halls, cafeterias and laboratories, inadequate lighting levels can lead to health problems for both educators and students, causing a loss of motivation and resulting in learning difficulties [28]. Therefore, in educational environments, it is crucial to ensure that when natural daylight is insufficient, the artificial lighting systems provide illumination that meets standard levels. Moreover, ensuring an even distribution of artificial light is of great importance. Additionally, from the perspective of energy efficiency, it is well-known that replacing outdated lighting equipment with new-generation (LED) luminaire significantly contributes to energy savings. In this context, the study aims to model lighting systems more effectively and provide guidance on energy conservation.

Due to the variability in daylight, the type, quantity, power and location of lighting systems designed to create evenly distributed illumination and ensure energy savings in educational buildings, such as classrooms and laboratories, are crucial. Hakkari University has not yet fully completed the installation of these systems across all its units. As a result, no lighting measurements or related performance studies have been conducted in any of the existing buildings at the Zeynelbey Campus. In this context, the project aims to conduct lighting level measurements at various points within a designated classroom in the Central Classroom building at Hakkari University's Zeynelbey Campus. The results will be compared and evaluated against the standards outlined in TS EN 12464-1 – Light and Lighting – Lighting of Workplaces [29]. In this context, the lighting performance of a relatively new educational building with a short service life will be determined and any deficiencies will be identified early to ensure timely corrective actions. Consequently, the lighting performance studies conducted within this project are of paramount importance for ensuring visual comfort in educational spaces, allowing activities to be performed efficiently, without strain or fatigue.

In this study, the illuminance level measurements in a designated classroom within the Central Classroom building were conducted using a luxmeter, with the working plane (e.g., the surface of desks, tables, etc.) as the reference. Measurements were taken at several points (9 points) to determine the average illuminance level in the area in lux. Additionally, both the spatial characteristics of the measured areas (such as wall and ceiling color, luminaire height, area dimensions, etc.) and the technical specifications of the lighting devices used (such as power consumption and luminous intensity) were examined. Care was taken to ensure that no light-blocking or refracting elements were present during the measurements in the designated spaces. The classroom featured a white ceiling, beige walls and floor sections, with the reflectance coefficients of the working plane selected to be the most suitable. The obtained illuminance levels were analyzed and evaluated according to the TS EN 12464-1 standard. For spaces where the specified standards were not met, recommendations were made for reducing the number of existing luminaire or replacing them. The lighting elements in the modeled classroom under current conditions consist of 12 units of 60*60 cm 36 W LED panel luminaire (imported products). Based on the measurements taken, a 2D view of the modeled classroom in the DIALux environment and the average illuminance values obtained from 9 different points using the lux meter are shown in Figure 3.

Figure 3. The 2D view and average illuminance levels of the classroom modeled in the DIALux environment (DIALux ortamında modellenen sınıfın 2D görünümü ve ortalama aydınlık düzeyleri)

The methodology established for this study is as follows: First, lighting calculations were conducted using the layout and photometric data of the 12 imported 60*60 cm 36 W LED panels installed in the selected classroom (Z12) within the Central Classroom building. Following this, calculations were performed for the same area using different LED panel luminaires with varying luminous flux and specifications, including power ratings of 30 W, 36 W and 42 W. The results obtained are presented in Tables 1 and 2. For each LED panel with different power ratings, a lighting design was created and evaluations were made based on the most suitable model. The light distribution and photometric outputs obtained from the existing LED panel luminaires in the classroom are shown in Figure 4. Comparisons among the other luminaires with different power ratings and lighting characteristics will be conducted based on these reference conditions according to the TS EN 12464-1 standard.

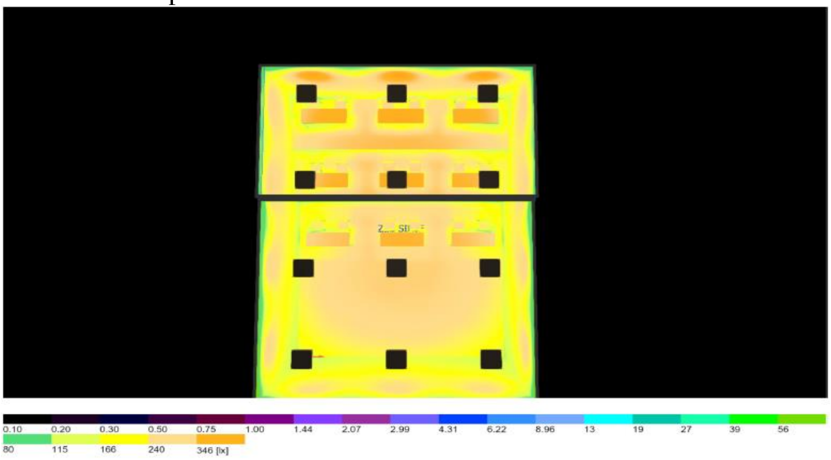


Figure 4. Illuminance levels of the classroom modeled in the DIALux environment with existing luminaires (Mevcut armatürler ile DIALux ortamında modellenen sınıfın aydınlık düzeyleri)

Under the current lighting conditions (36 W, 60×60 cm LED panel, 3300 lm, 4000 K), the illuminance levels obtained do not demonstrate an even distribution of lighting within the classroom. According to the TS EN 12464-1 standard, the required illuminance level for classrooms and specialized lecture rooms is 300 lux. When examining the illuminance distribution in Figure 3 and Figure 4, it is observed that the maximum illuminance distribution reaches 346 lux. However, this distribution is not uniformly present throughout the classroom or in areas where higher lighting is needed; instead, it is predominantly found on some walls and outside the central area of the classroom. In this context, a comparison will be made based on values such as illuminance level and light quantity using LED panel luminaires with identical characteristics but varying power ratings (30 W, 36 W and 42 W) and different specifications (light output - lumens) as designed in the DIALux environment.

4. FINDINGS AND DISCUSSION (BULGULAR VE TARTIŞMA)

The aim of this study is to investigate the lighting performance of classrooms, which are among the most heavily used areas in university campus buildings, by comparing the lighting performance of the currently used luminaire with LED panel luminaires of different power levels developed using next-generation technology. The lighting performance results obtained from the area studied can subsequently be applied to different buildings and spaces, allowing for the evaluation of lighting performance in these areas. For this purpose, the illumination levels obtained from 30 W, 36 W and 42 W LED panel luminaires were compared without altering the existing lighting arrangement in the studied area. In this way, the deficiencies of the current lighting system compared to LED panel luminaires of other power levels were identified and the most suitable lighting system was determined based on the data.

For the designated classroom (Z12), a model with 12 units of 60*60 cm LED panels, each with 30 W, 3972 lm and 4000 K specifications, was initially implemented. Figure 5 shows the light levels achieved in the classroom modeled in DIALux with the LED panels of the specified characteristics. Upon examining Figure 5, it can be seen that a highly uniform light distribution covering the entire classroom was achieved with the 30 W LED panels providing 3972 lm of light. Additionally, the 300 lux value specified for classrooms in the TS EN 12464-1 standard was met. In this context, this model provides a more economical and efficient lighting level.

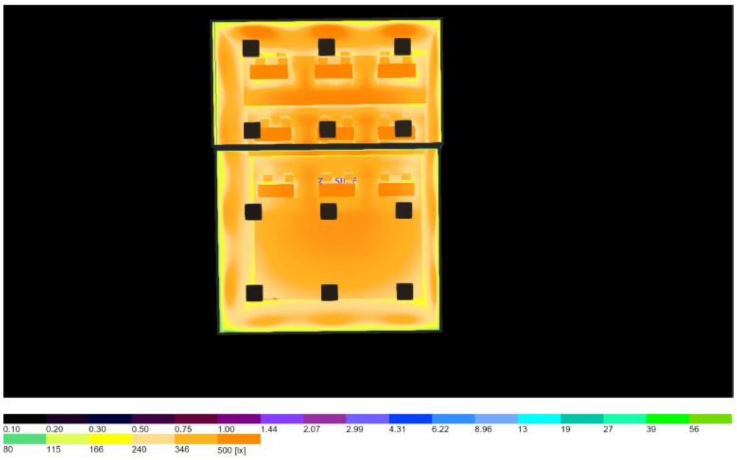


Figure 5. Light levels of the classroom modeled in DIALux with 30 W luminaire (30 W armatürler ile DIALux ortamında modellenen sınıfın aydınlık düzeyleri)

Figure 6 displays the characteristics, photometric output, light distribution curve and the distribution of average light levels within the classroom for the 30 W LED panel luminaire. Although some areas show a reduction in light levels due to the efficiency of the LED panel used in this model, the average light levels on the work desks, seats and chalkboard plane are observed to be compliant with the TS EN 12464-1 standard. This indicates that the model meets the minimum illumination requirements for the classroom environment. Additionally, the high switching frequency of the LED panels contributes to an extended lifespan. Compared to the current 36 W, 3300 lm LED panel luminaire, there is a reduction in power consumption, suggesting potential energy savings.

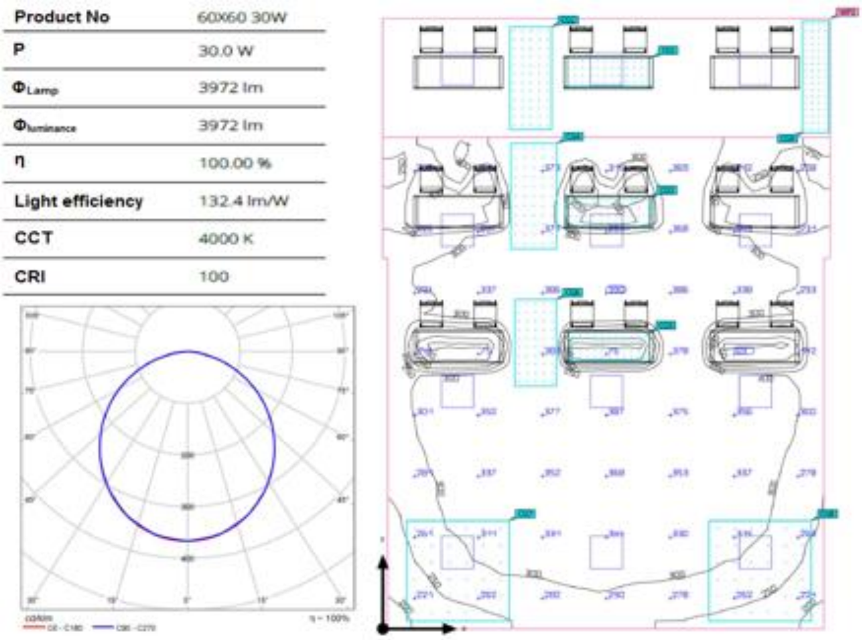


Figure 6. Light distribution curve and average illumination levels obtained with 30 W luminaire in the classroom modeled in the DIALux environment (DIALux ortamında modellenen sınıfın 30 W armatürler ile elde edilen ışık dağılım eğrisi ve ortalama aydınlık düzeyleri)

The current luminaire in the classroom is rated at 36 W and provides 3300 lm. However, as shown in Figure 5, the light and illumination distribution is not uniform. Therefore, a new DIALux model was designed using the same number of LED panel luminaire with 4558 lm at the same power. The illumination levels for this model are shown in Figure 7. While a decrease in illumination levels is observed in some areas, the central areas of the classroom meet the average illumination level requirements according to the TS EN 12464-1 standard, thus meeting the minimum illumination level criteria for the space. However, the edge areas are observed to be closer to the 300 lux standard value.

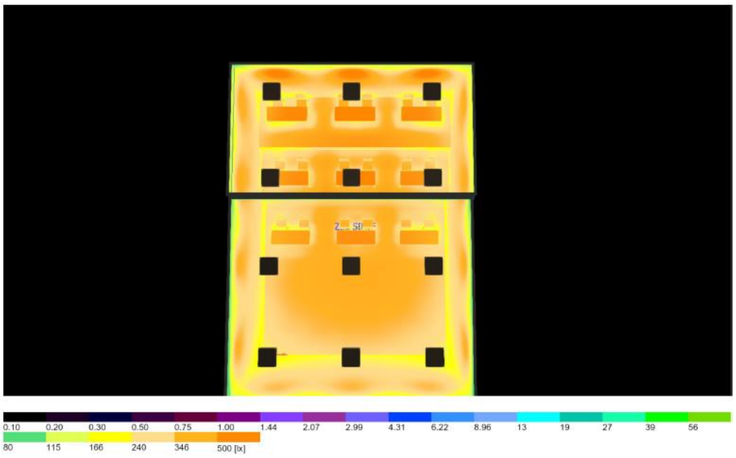
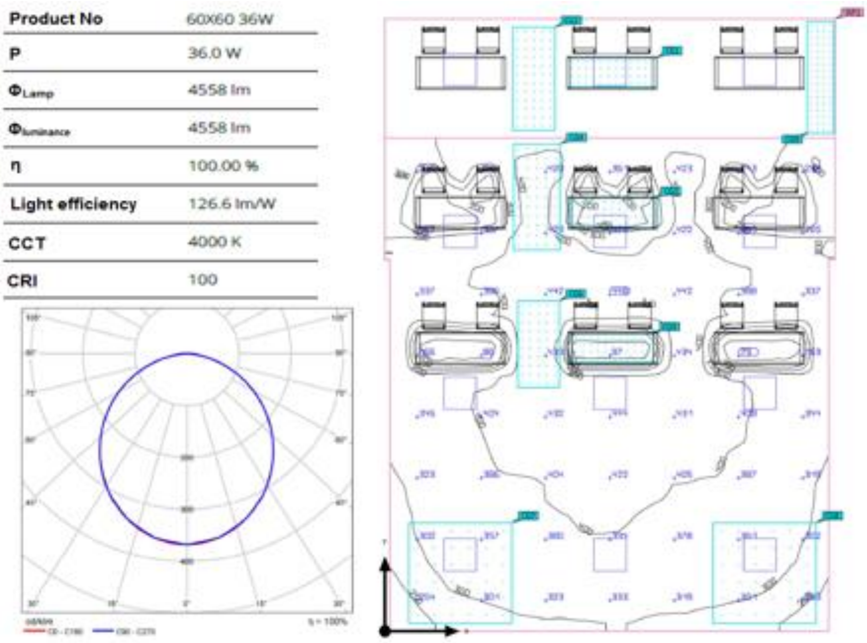


Figure 7. Light levels of the classroom modeled in DIALux with 36 W luminaire (36 W armatürler ile DIALux ortamında modellenen sınıfın aydınlık düzeyleri)

Figure 8 shows the characteristics, photometric output, light distribution curve and average illumination level distribution within the classroom for the LED panel luminaire rated at 36 W and providing 4558 lm. This luminaire has created a more uniform lighting model compared to the current situation. However, it is observed that the illumination level in this model is closer to the standard values at the center of the classroom.



Product No	60X60 36W
P	36.0 W
Φ_{Lamp}	4558 lm
$\Phi_{luminance}$	4558 lm
η	100.00 %
Light efficiency	126.6 lm/W
CCT	4000 K
CRI	100

Figure 8. Light distribution curve and average illumination levels obtained with 36 W luminaire in the classroom modeled in the DIALux environment (DIALux ortamında modellenen sınıfın 36 W armatürler ile elde edilen ışık dağılım eğrisi ve ortalama aydınlık düzeyleri)

Finally, Figure 9 shows the illumination levels of the classroom modeled in DIALux with a 42 W luminaire. The lighting design for the classroom with the 42 W LED panel achieved illumination levels significantly above the values specified in the TS EN 12464-1 standard at nearly every point. The use of a LED panel luminaire with this power and specification is not suitable for such a workspace in terms of both illumination level and economic considerations. The same level of illumination and light output can be achieved with a 30 W LED panel luminaire.

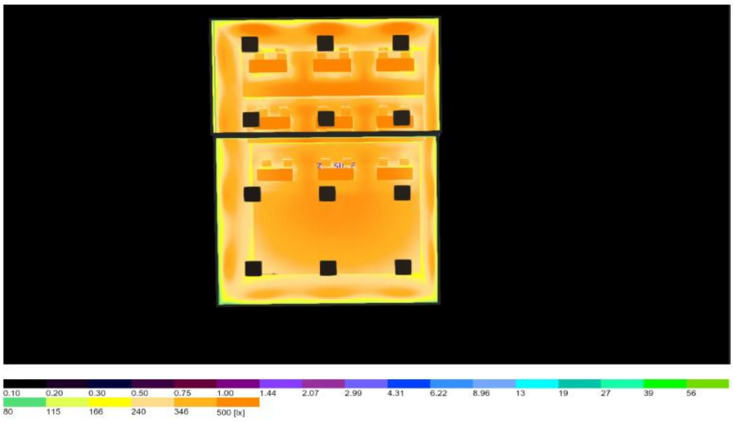


Figure 9. Light levels of the classroom modeled in DIALux with 42 W luminaire (42 W armatürler ile DIALux ortamında modellenen sınıfın aydınlık düzeyleri)

Figure 10 shows the specifications, light distribution curve and average illumination levels of the LED panel luminaire with 42 W power and 5296 lm light output. With this LED panel, the illumination levels in the classroom are significantly high, with the intensity being particularly high at the central point. The illumination levels achieved in these areas are well above the values specified in the TS EN 12464-1 standard. Therefore, due to both the excessive illumination level and light output, as well as the high power consumption, the use of this lighting model is not suitable.

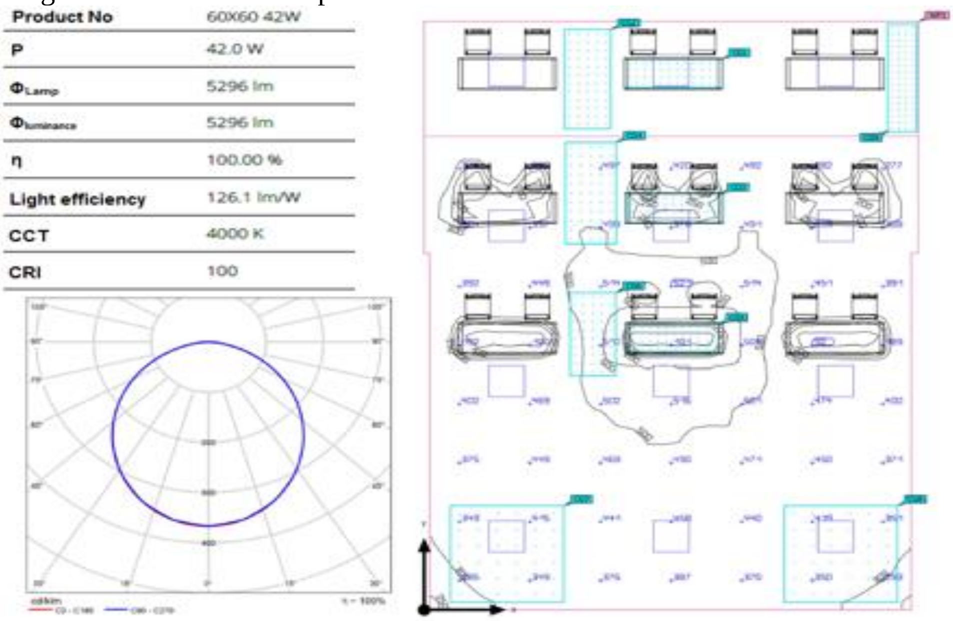


Figure 10. Light distribution curve and average illumination levels obtained with 42 W luminaire in the classroom modeled in the DIALux environment (DIALux ortamında modellenen sınıfın 42 W armatürler ile elde edilen ışık dağılım eğrisi ve ortalama aydınlık düzeyleri)

Table 1 presents the specifications and calculated values for all the models included in the study. The number of luminaire used for both the existing and other LED panel models was kept constant at 12. Additionally, the light outputs of all the models are varied, resulting in different total light flux values in the working area. For instance, the light efficacy of the existing 36 W LED panel and another 36 W LED panel with different light outputs was calculated as 91.7 lm/W and 126.6 lm/W, respectively, showing a significant difference. Furthermore, the illumination levels on the working planes were calculated as 247 lx and 341 lx, respectively. The minimum and maximum average illumination levels obtained from different points within the working area for each model were also computed. In this context, the calculations for the 30 W LED panel luminaire yielded illumination values that were consistent with the standard values and demonstrated uniform lighting. Conversely, the lighting models with 36 W and 42 W LED panels did not provide a uniform distribution of light across the entire surface of the classroom. This results in increased power consumption and unnecessary energy expenditure.

Table 1. Specifications of the 60*60 LED panel luminaire in the modeled classroom (Modellenen sınıfdaki 60*60 LED panel armatür özellikleri)

Specifications	**36 W LED Panel** (Current Model)	**30 W LED Panel**	**36 W LED Panel**	**42 W LED Panel**
Number of luminaire	12	12	12	12
Φ	3300 lm	3972 lm	4558 lm	5296 lm
Φ_{total}	39600 lm	47664 lm	54696 lm	63552 lm
P_{total}	432.0 W	360.0 W	432.0 W	504.0 W
Light Efficiency	91.7 lm/W	132.4 lm/W	126.6 lm/W	126.1 lm/W
Specific Link Value	4.68 W/m^2=1.89 W/m^2/100 lux	3.90 W/m^2=1.31 W/m^2/100 lux	4.68 W/m^2=1.37 W/m^2/100 lux	5.46 W/m^2=1.38 W/m^2/100 lux
$E_{vertical\ (working\ plane)}$	247 lx	297 lx	341 lx	397 lx
$E_{min\ (working\ plane)}$	39 lx	47 lx	53.9 lx	62.6 lx
$E_{max\ (working\ plane)}$	327 lx	393 lx	451 lx	524 lx
U_0	0.16	0.16	0.16	0.16
Consumption Quantities (Max. 3250 kWh/a)	1069 kWh/a	891 kWh/a	1069 kWh/a	1247 kWh/a

In the study, calculations were performed at 9 different points, as shown in Figure 3, to better determine the classroom lighting levels modeled in DIALux using LED luminaire with varying power and characteristics. The distance of these points from the LED panels mounted on the ceiling varies, resulting in changes in lighting levels at these points. The standard illumination level specified for classrooms in TS EN 12464-1 is 300 lux. However, the minimum, maximum and average values of the illumination levels in each case are considerably higher in some points. In fact, even the 30 W LED panel with the lowest power exceeds the standard illumination levels in some locations. Nevertheless, the distribution of illumination and light intensity is more uniform with the 30 W LED panel. Therefore, it is deemed appropriate to replace the current 36 W LED panel luminaire with the 30 W LED panel luminaire. The minimum, maximum and average illumination levels created by LED panel luminaire with different powers and characteristics at various points in the classroom where the study was conducted are presented.

Table 2. Illumination levels at different points of the modeled classroom with 60*60 LED panel luminaire (Modellenen sınıfdaki 60*60 LED panel armatürlerin farklı noktalardaki aydınlık düzeyi)

Working Plane	**36 W LED Panel** (Current Model)			**30 W LED Panel**			**36 W LED Panel**			**42 W LED Panel**		
	E (lx)	E_{min} (lx)	E_{max} (lx)	E (lx)	E_{min} (lx)	E_{max} (lx)	E (lx)	E_{min} (lx)	E_{max} (lx)	E (lx)	E_{min} (lx)	E_{max} (lx)
1 (1.884 m)	371	350	383	446	421	461	512	484	529	595	562	614
2 (0.974 m)	265	178	312	319	215	375	366	246	431	426	286	500
3 (1.382 m)	358	350	364	431	421	438	494	483	503	574	562	584
4 (0.472 m)	276	241	301	332	290	362	381	332	415	443	386	483
5 (0.910 m)	330	326	332	397	393	399	455	451	458	529	524	532
6 (0.000 m)	263	235	276	317	282	332	364	324	381	423	376	443
7 (0.000 m)	202	158	241	243	190	290	279	219	333	324	254	387
8 (0.000 m)	199	154	239	239	185	287	275	213	330	319	247	383
9 (0.974 m)	174	92.4	236	210	111	284	241	128	326	280	148	379

4.CONCLUSIONS (SONUÇLAR)

The analysis and evaluation of lighting levels in classrooms at the Central Classroom building of Hakkari University's Zeynelbey Campus, based on the lighting level measurements to be conducted, are of great importance for future generations and the national economy. In this context, the Presidential Decree published on November 4, 2023, amended the previously set 15% energy savings target to a minimum of 30% by 2030 for public buildings required to have an energy manager, with the aim of improving energy efficiency and reducing costs. It is also necessary to reduce lighting expenses within a specific program and achieve energy savings in educational institutions to meet this target. This involves examining existing lighting systems, reducing luminaire that provide illumination above the standard level, designing lighting systems with different characteristics and replacing them with new-generation lighting technologies to create more advantageous conditions. Thus, significant contributions will be made to the state budget and the national economy.

In this study, the comparison of illumination levels, light output and energy efficiency was conducted by using LED panel luminaire with different power and characteristics, as opposed to the commonly used existing LED panel luminaire in classroom lighting at educational institutions. Measurements of the illumination levels created by the current lighting system were taken at various points in the designated classroom using a luxmeter and a lighting model was created in the DIALux environment. Comparisons were made to create a more efficient lighting environment using different LED panels through this model. According to the TS EN 12464-1 standard, the minimum illumination level requirements were met with the new LED panels at most points in the classroom environment; however, the average illumination level was not achieved with the currently used LED panels. It was found that the most suitable lighting model for the specified area is the 30 W LED panel luminaire, which consumes less energy compared to other models. Thus, it was concluded that the 30 W LED panel is more appropriate and investable compared to other LED panel luminaire. The results indicate that while other LED panels are also suitable for the area, they create excessive illumination levels and light output, leading to higher energy consumption and, therefore, are less suitable. It is believed that more economical lighting systems can be developed by increasing the effectiveness of natural light sources in these areas.

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DECLARATION OF ETHICAL STANDARDS
(ETİK STANDARTLARIN BEYANI)

The author of this article declares that the materials and methods they use in their work do not require ethical committee approval and/or legal-specific permission.

Bu makalenin yazarı çalışmalarında kullandıkları materyal ve yöntemlerin etik kurul izni ve/veya yasal-özel bir izin gerektirmediğini beyan ederler.

AUTHORS' CONTRIBUTIONS (YAZARLARIN KATKILARI)

Erşan Ömer YÜZER**:** He conducted the literatüre review, designed the project, analyzed the results and performed the writing process.

Literatür taraması yapmış, projeyi tasarlamış, sonuçlarını analiz etmiş ve makalenin yazım işlemini gerçekleştirmiştir.

CONFLICT OF INTEREST (ÇIKAR ÇATIŞMASI)

There is no conflict of interest in this study.

Bu çalışmada herhangi bir çıkar çatışması yoktur.

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