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INVESTIGATION OF SAVING METHODS IN ROAD LIGHTING

Abstract

The most important effect of road lighting is that accidents can be prevented. It also improves the visibility of pedestrians and ensures that drivers can travel safely and comfortably. In road lighting, while photometric values in international standards are provided, it also required to be economical at the same time. In Turkey, the amount of energy spent for lighting between 1970-2016 constitutes 2.6% of total energy. There are various methods to save energy from road lighting, which constitutes a large part of the amount of electricity consumed. In this study, firstly, the light sources used in road lighting are examined and the advantages of LED lamps are emphasized. In the road lighting to be implemented in Turkey, the effect of the conversion project to LED light sources on energy saving was mentioned. In addition, the study logic and differences of intelligent road lighting systems were mentioned and compared with energy saving. These methods have been compared in terms of energy saving and economical contribution without compromising the safety of drivers and pedestrians.

Keywords: Energy efficiency, Road lighting, LED conversion, Intelligent road lighting

YOL AYDINLATMASINDA TASARRUF YÖNTEMLERİNİN İNCELENMESİ

Özet

Yol aydınlatmasının en önemli etkisi kazaların oluşmasının önüne geçilebilmesidir. Ayrıca yayaların görme koşullarını iyileştirmekte; sürücülerin güvenli

ve rahat yolculuk yapmalarını sağlamaktadır. Yol aydınlatmasında uluslararası standartlardaki fotometrik değerler sağlanırken aynı zamanda ekonomik olması istenmektedir. Ülkemizde 1970-2016 yılları arasında aydınlatma için harcanan enerji miktarı toplam enerji miktarının % 2,6'sını oluşturmaktadır. Tüketilen elektrik miktarının büyük bir kısmını oluşturan yol aydınlatmasından tasarruf sağlamak için çeşitli yöntemler bulunmaktadır. Bu çalışmada yol aydınlatmasında kullanılan ışık kaynaklarının incelenmesi yapılmış ve LED lambaların üstünlükleri vurgulanmıştır. Türkiye'de uygulanmaya başlanacak mevcut ışık kaynaklarının LED ışık kaynaklarına dönüştürülmesi projesinin enerji tasarrufuna etkisinden bahsedilmiştir. Ayrıca uygulanmakta olan akıllı yol aydınlatma sistemleri yapısından, farklılıklarından ve enerji tasarrufu yönünden kıyaslaması yapılmıştır. İncelenen bu yöntemlerin sürücülerin ve yayaların güvenliğinden ödün vermeksizin enerji tasarrufu ve ekonomik katkı sağlaması yönünden karşılaştırması yapılmıştır.

Anahtar Kelimeler: Enerji verimliliği, yol aydınlatma, LED dönüşüm, akıllı yol aydınlatması

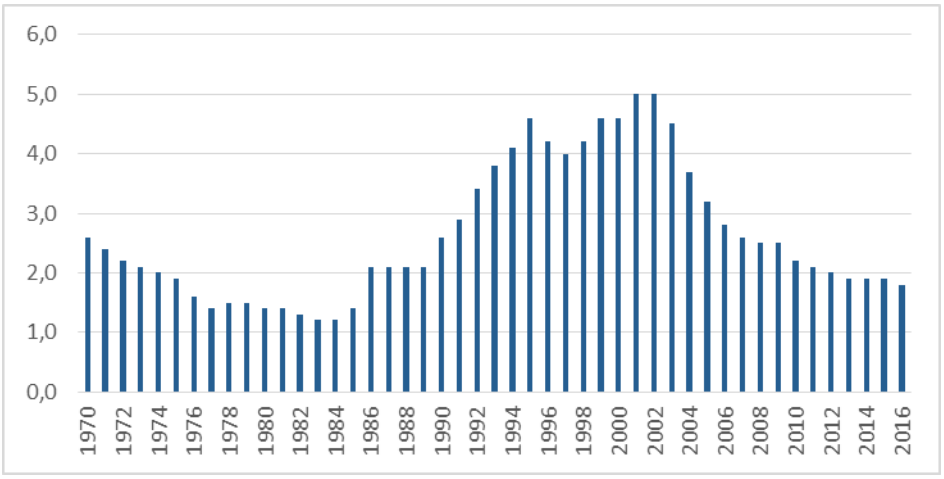
1. Introduction

There must be some basic features of correct illumination. One of them must be human-focused. In the case of human-focused lighting, it is desirable that the lighting be balanced and uniform for visual comfort. It should be enough to provide the conditions to see; it should not be too tired to look or glare. In addition, dark and bright areas should be avoided on the road, a homogeneous lighting should be provided.

Lighting is an important sector of contemporary life. A number of various actions can be taken in order to make lighting sector more efficient and conserve satisfactory energy amounts. The electrical energy consumption of street and outdoor lighting constitutes an important part of total energy consumption (Walraven & Echelon, 2006; Zotos et al., 2012). Lighting represents 15-20% of the world yearly electricity, and 3% of the total electricity consumption goes to road lighting, e.g. Road lighting consumes 14 billion kWh annually in the United States. Public lighting system represents about 6% of the Chinese yearly electricity demand, and most of which goes to road lighting (Fusheng et al., 2009). In 2007, road lighting and traffic signals in the UK consumed 2.5 TWh of electricity annually (DEFRA, 2008). Although this represents only 0.73% of the total annual electricity consumption of the UK (ONS, 2008), it is of considerable symbolic significance for energy conservation being both conspicuous and financed by taxes (Boyce et al., 2009). Since possibilities for energy savings in street lighting are numerous and since some of them enable reductions in electricity consumption of even more than 50% (Kostic & Djokic, 2009).

Nowadays, street lighting accounts for 53% of outdoor lighting use worldwide (11 554 TWh yearly) (Johansson et al., 2014; Farahat et al., 2015). Furthermore, the outdoor lighting market continues to grow (compound annual growth rate of the outdoor lighting market is estimated to be 42% in the period of 2011–2020 (Jurvansuu & Belloni, 2013; Farahat et al., 2015). In a context of rising energy prices and growing environmental awareness, the aforementioned trends call for improvements in street lighting efficiency (Farahat et al., 2015).

The impact of road lighting on total electricity consumption in Turkey between 1970-2016 has changed between 1.2% and 5% as shown in Figure-1. In 2016, the ratio of road lighting to electricity consumption in Turkey was 2.6% (TUİK, 2018).



GRAPH 1: ***Ratio of Road Lighting in Total Electricity Consumption in Turkey (TUİK, 2018)***

In this study, the following energy saving methods used in road lighting were examined:

- LED lighting,
- Converting light sources to LED light sources,
- Intelligent lighting system.

2. Converting light sources to LED light sources

Low pressure sodium (LPS) lamps were first installed in 1932, high pressure mercury vapour in 1933, fluorescent in 1946 and high pressure sodium (HPS) in 1966 (Cornwell, 2017; Fotios & Gibbons, 2017; Boyce et al., 2009). LED technology has rapidly developed in recent years to the point that LEDs can be seriously considered for replacing conventional halogen and incandescent lamps in street lighting (Nuttall et al., 2008).

Currently energy savings in lighting are achieved via the switch from traditional light sources to more efficient ones such as LEDs (Juntunen et al., 2013). LED technology offers high efficiency, good physical robustness, long life expectancy and low power consumption (Almeida et al., 2014; Jägerbrand, 2016; Kumar, 2013). LED lighting is easy dimmable and has a rapid on/off time, which is very appropriate for application of dimming schemes to further reduce energy consumption (Almeida et al., 2014; Beccali et al., 2015; Jägerbrand, 2016)

Worldwide, Light Emitting Diode (LED) is emerging as the most energy efficient technology for lighting applications. Most of the existing applications focus on replacing existing street lighting units with the more energy efficient LED, but without any type of control to take advantage of its usage pattern (Pipattanasomporn et al., 2014). For all the analysed scenarios, the results of an economic analysis are quite satisfactory, provided that the LED cost is today

relatively high. This factor is counterbalanced by the very high achievable savings in energy consumption and maintenance costs (Beccali et al., 2015).

Within lighting technologies, Light Emitting Diodes (LEDs) assure the possibility of switching on the lamp without the preheating typical of halogen ones; a very high lighting efficiency; low power consumption; a superior life time and quick switching times not comparable to those of older technologies (only incandescent lights have a lower lighting time, but with very big power consumption and the shortest time life); less sensitivity to transient phenomena, which have a big impact on other technologies, allowing thousands of lightings without the risk of lamp failure (Leccese et al., 2014).

Energy-saving direction, with no lighting control, is to change the old lighting system with more sophisticated and energy saving equipments. For example, in (Hyodhyad & Srikaew 2010) by replacing the old system in Thailand by a new high pressure sodium (HPS) road lighting, they saved up to 25% - 30% of the energy. Similar related work to this trend is by using the LEDs (Li et al., 2009) lamps that can consume only the quarter of the HPS lamps and give almost the equivalent luminous efficacy (Samir & Elsagheer, 2013).

In Turkey, "Procedures and Principles on the Use of LED Luminaires in General Lighting" was published on 23.01.2015. This regulation includes the preparation of lighting conversion plans and projects for the use of LED luminaires in road lighting, approval of investment plans and projects, the investments made by electricity distribution companies and the acceptance processes of the facilities (TEDAŞ, 2015).

Republic of Turkey Ministry of Energy and Natural Resources conducted by the National Energy Efficiency Action Plan, 30% of the 7.5 million street lights is expected to change until 2023 (Ulusal Enerji Verimliliği Eylem Planı 2017-2023, 2017). In Turkey, 5 pilot projects were carried out within the scope of transition to LED lighting in road lighting. As a result of these pilot studies, a saving rate of around 40% was found (Sokak ve cadde aydınlatmasında yüzde 40 tasarruf, 2015). Türkiye'de LED aydınlatmaya geçiş çalışmaları sonucunda yıllık 180 milyon lira tasarruf olacağını düşünülmektedir. 2023-2033 arasında bu rakam 600 milyon liraya çıkacağı planlanmaktadır. As a result of the transition to LED lighting studies in Turkey, it is thought that 180 million Turkish lira will be saved annually. Between 2023-2033, this figure is expected to increase to 600 million Turkish lira (Albayrak, 2018).

3. Intelligent lighting system

Traditional road lighting systems consume a large amount of energy. When the ambient light falls under a certain threshold, all the luminaries are turned at full-power without considering user perception and interaction (Atıcı et al., 2011).

The external luminance, the climatic conditions as limpid sky or haze, the road surface wet or dry, the traffic speed and the related safe driver stopping distance, strongly influence the quantity of artificial support light necessary (Carni et al., 2013).

Without giving up road lighting quality criteria, it is only possible to achieve the required level of lumination, by following the changes in traffic volume, meteorological conditions and unexpected situations like accidents on the road and the conditions on the road and

adjusting the luminous flux value of the lamps with an automation system. By the installation of these systems energy savings up to %30 - %40 are said to be achieved (Büyükkınacı, 2008).

Due to the maintenance factor, the light output of luminaires may be excessive when the lamps are new whereas lower than required as lamps are aged. By considering the maintenance factor, better lighting quality and considerable energy savings can be achieved from maintaining constant light output when needed. If the budget allows, a luminous flux sensor can be installed in each luminaire to detect the depreciation of luminous flux.

The intelligent lighting system (Hung et al., 2011) refers to a system where multiple lighting fixtures are connected to a network, and user needs are met by cooperation of the various lighting fixtures. It can have autonomous distributed control. That is, there is no element with control over the entire system. Illuminance at each location is controlled by having each light perform learning operation. The system has high robustness against malfunction, and a high reliability system can be achieved even in large-scale buildings. It is easy to add lighting fixtures and illuminance sensors, and there is no need, at installation, to layout information for each lighting fixture or illuminance sensor. It is possible to switch on lighting devices with any desired luminance. Therefore, the system conserves energy by not switching on unneeded lighting fixtures (Kumar, 2013).

The intelligent road lighting systems from Muhendra and Arzi (2017) provide wifi-based remote control and monitoring. The sensor nodes are also installed several sensors such as lighting sensors, humidity sensors, temperature sensors and current sensor to monitor environmental conditions.

To reach the purpose of energy saving, it introduces an information method to deal with the problem of road lighting. The road lighting intelligent control system is based on wireless network control that can implement real-time monitoring for road lighting, intelligent work without manual intervention. The design method of road lighting intelligent control system, which was built up by wireless personal network technology, GPRS, microprocessor and host computers, and researched on the system including the structure, key technologies, software design and encryption. Road lighting intelligent control system based on wireless network control has been tested in small scale for more than two months. The result shows that it has remarkable energy-saving effect, can save energy up to 40% the system is stable and reliable, and communication data loss rate is lower than 3% the software has a friendly interface and convenient operation control. (Li et al., 2009,b).

A smart city application has been realized and tested. It is a fully remote controlled isle of lamp posts based on new technologies. It has been designed and organized in different hierarchical layers, which perform local activities to physically control the lamp posts and transmit information with another for remote control. Locally, each lamp post uses an electronic card for management and a ZigBee tlc network transmits data to a central control unit, which manages the whole isle (Leccese et al., 2014).

Today, many companies offer intelligent road lighting. Philips, one of them, promises up to 50% energy savings thanks to intelligent road lighting. They are a system that supports sys-

tem sensors, cameras and other IoT devices. It also allows you to manage lighting through the control panel, calculate energy usage, and monitor system health (Philips CityTouch, 2018).

Atıcı et al. (2011) designing an intelligent road lighting system is a necessity because of the inefficiencies in the traditional systems. We investigated intelligent road lighting systems from user experience, technology, energy perspectives and proposed useful services that can be enjoyed using the same infrastructure.

A web-based management system for urban road lighting is developed for the purpose of energy-saving. Our system consists of a platform of remote monitoring and management of street lamps, a database management module, a road controller (Smart Server), and a GPRS wireless communication module. Extensive tests show good performance of our system for energy-saving (Zhang et al., 2010).

In China, a project involving 8000 street lamps (1350 street lamps in the first stage) was carried out with a dimmable road lighting system with intelligent remote control. The proposed system in this paper provides an environmentally friendly and energy-saving solution for dimmable road lighting systems. In phase-one of this project, an overall energy saving of 27% has been recorded without adversely affecting quality of life (Chung et al., 2005).

Energy can also be saved when the streetlight is dimmed adapting its light level to the changing natural light during sunrise and sunset. An example of a 63% power decrease for about 30 minutes during sunrise is shown in this paper (Juntunen et al., 2013).

Time schedule based step dimming is a commonly used control strategy nowadays in telemanagement road lighting control systems (Walraven & Echelon, 2006). The lamp light output is controlled centrally and can be adjusted to two to four dimming levels according to preset time schedule. The dimming schedule is essentially based on traffic volume, and lamp switch on/off time are controlled by photocell and/or timer (Guo et al., 2013).

Yan and Hui (2006) in their project, a highly energy-efficient central energy-saving system is used to control large high-intensity-discharge (HID) lamp road lighting networks. Dimming characteristics of the HID lamps (widely used in Road Lighting Systems) from 50W to 400W and energy saving capability of the central dimming unit are recorded. The results show that dimmable magnetic systems have many favorable features in terms of energy saving and environmental protection.

Traditional road lighting is inadequate in terms of energy efficiency. The use of energy saving methods in road lighting is an undeniable fact. LED road lighting conversion projects and intelligent road lighting systems are the most important energy solutions.

The principles for LED conversion projects are legally determined. For the applicability of the projects, it is necessary to provide the minimum thresholds for energy efficiency as specified in the law. It will take a long time because conversion to LED fittings will be costly.

Although it is certain that intelligent road lighting systems will have a positive impact on road lighting in terms of energy efficiency, it is not possible to make clear how effective it will be. The reason for this is that the hardware and software used in each system is different. Since there is no legal procedure for intelligent road lighting systems, there is no lower limit for energy saving. Intelligent road lighting systems need to be examined in terms of energy efficiency and defined as standard. Thus, adequate energy saving systems can be avoided.

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