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Comparative analysis of different LED lamps with reference to EU's ecodesign and energy labeling regulations in Türkiye

Türkiye'deki farklı LED lambalarının AB'nin eko tasarım ve enerji etiketleme düzenlemeleri bağlamında karşılaştırmalı analizi

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Abstract

The lighting industry, which was unaffected by the economic downturn triggered by the COVID-19 pandemic, recorded a growth of 2.5% in 2020. The global lighting market, valued at approximately 118.33 billion USD in 2019, is expected to reach 163.72 billion USD by 2027. In Turkey's imports of electric lighting devices, China leads with a 49% share, while EU countries such as Germany, Romania, Italy, the Czech Republic, France, and Poland are also significant import partners. As a candidate country for the EU, Turkey must align its products, particularly solid-state lighting equipment, with EU regulations. This study was prepared using LED lamps from ten different brands, both domestic and imported, available in the Turkish market. The lamps were tested under the Energy Labeling Regulation (EU) 2019/2015 and photometric analyses were conducted. The results indicate that all LED lamps fall into the 'F' and 'G' energy classes under the new labeling rules. Although the sample size is limited, this study highlights the need to improve the efficiency of LED lamps in Turkey while technically complying with the new energy labeling regulations, and provides a reference for manufacturers aiming to enter the Turkish and EU LED markets.

Keywords: Efficiency label, Energy efficiency, EU Regulations, LED manufacturers

Öz

COVID-19 salgınının tetiklediği ekonomik durgunluktan etkilenmeyen aydınlatma endüstrisi, 2020 yılında %2,5 oranında bir büyüme kaydetmiştir. 2019 yılında yaklaşık 118.33 milyar ABD doları değerinde olan küresel aydınlatma pazarının, 2027 yılında 163.72 milyar ABD dolarına ulaşması beklenmektedir. Türkiye'nin elektrikli aydınlatma cihazları ithalatında Çin %49'luk bir payla başı çekerken, Almanya, Romanya, İtalya, Çek Cumhuriyeti, Fransa ve Polonya gibi Avrupa Birliği (AB) ülkeleri de önemli ithalat ortakları arasındadır. AB adayı bir ülke olarak Türkiye, özellikle katı hal aydınlatma ekipmanları için ürünlerini AB düzenlemeleriyle uyumlu hale getirmek durumundadır. Bu çalışma, Türkiye pazarında satışta olan yerli üretim ve ithal toplam on farklı markanın LED lambaları kullanılarak hazırlanmıştır. Lambalar, Enerji Etiketleme Yönetmeliği (AB) 2019/2015 kapsamında test edilmiş ve fotometrik analizler yapılmıştır. Sonuçlar, tüm LED lambaların yeni etiket kuralları altında "F" ve "G" enerji sınıflarına girdiğini göstermiştir. Bu çalışma, her ne kadar örneklem büyüklüğü sınırlı olsa da, Türkiye'deki LED lambaların yeni enerji etiketleme düzenlemelerine teknik olarak uyum sağlamakla birlikte verimliliklerinin artırılması gerekliliğini ortaya koymakta ve Türk ve AB LED pazarına girmeyi hedefleyen üreticiler için bir referans oluşturmaktadır.

Anahtar kelimeler: Verimlilik etiketi, Enerji verimliliği, AB Yönetmelikleri, LED üreticileri

1 Introduction

Artificial light energy consumption is approximately 2,900 TWh, corresponding to 16.5% of the world's annual electricity production [1]. This consumption causes 5% of global greenhouse gas emissions. However, increasing population and urbanization are expected to lead to a 50 percent increase in artificial lighting demand by 2030 [2]. In 2020, approximately 219 billion kilowatt-hours (kWh) of electricity were used to light the residential and commercial sectors together in the U.S. It has been stated that this value constitutes approximately 6% of the total U.S electricity consumption. The development of Solid-State Lighting (SSL) technologies based on components such as LEDs, Organic light-emitting diodes (OLEDs), and Laser Diodes (LDs) instead of traditional lighting methods is of great importance in terms of energy efficiency, greenhouse gas emissions, and energy sustainability. Studies show that phasing out traditional lighting technologies by 2025 will prevent more than 15.2 million tons of carbon emissions [3]. Estimates by the United Nations Environment Program (UNEP)-Global Environment Facility (GEF) estimate that switching to efficient lighting in the Association of Southeast Asian Nations (ASEAN) could result in annual electricity savings of over US$3.5 billion. Thus, electricity

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consumption is expected to decrease by 35 TWh, while CO2 emissions are expected to decrease by 20 million tons [4].

In 2020, Europe utilized nearly 11 billion lamps, equating to over 24 lamps per citizen in the EU27. Projections for 2030 estimate that the residential sector in the EU will see the installation of 6.4 billion lamps, equating to 32 lamps per hour, with an annual electricity consumption of 27 TWh. It is anticipated that over 96% of the lamps installed in 2030 will be LED lights [5].

LED technology continues to evolve with increasing Luminous Efficacy and price-performance ratio while providing new opportunities for lighting design and energy savings [6, 7]. Figure 1 shows that while LED costs continue to fall, indoor LED lamp usage is advancing, and LED sales figures exceed fluorescent lamp sales figures. LED lamp sales had a 3.7% market share in the lighting market in 2013, which accounted for almost half of the total global lighting sales in 2019. LED lamps and equipment are expected to account for more than 90% of lighting product sales by 2030 [1]. The economic recession caused by the novel coronavirus contagious disease (COVID-19) could not prevent the LED market's growth rate of 2.5% in 2020, worth approximately $15.7 billion [8].

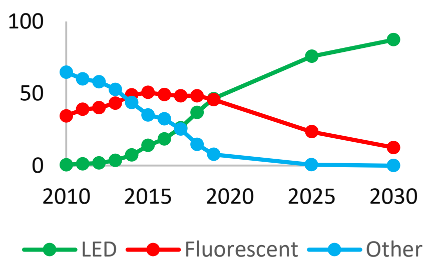


Figure 1. Global LED penetration rate by sales

The U.S. Department of Energy's (DOE) energy savings forecast for solid-state lighting in general illumination applications predicts that, by 2035, LED lighting will constitute 84% of total lighting sales, resulting in annual primary energy savings of 4.8 quadrillion British thermal units (BTU) [9]. Considering all these effects, the European Union has created new legal regulations that will phase out tungsten halogen and compact fluorescent lamps. It is expected to convert existing 1.3 billion conventional light sources to LED, allowing the EU to avoid approximately 100 million tons of CO2 emissions. Thus, it is aimed to save 270TWh of electricity. The EU lighting market, which was 16.3 billion Euros in 2012, reached an average of 19.8 billion Euros in 2020. This market will be estimated to exceed 30 billion euros by 2024 [10, 11].

Furthermore, governments are offering support and incentives to encourage consumer adoption of LED products. This involves implementing regulations to phase out older and less efficient lighting technologies, along with initiatives aimed at enhancing the overall efficiency of the lighting industry [1].

The first law guiding energy efficiency policies in Türkiye, an EU candidate country, is the Energy Efficiency Law No. 5627, which entered into force in 2007. This law aims to alleviate the burden of energy costs on the economy, to use energy effectively, to prevent waste, and to protect the environment [12]. In addition, many regulations, including targets related to the use of solid-state technologies in lighting energy systems, are being issued and tried to be put into practice. In the "Regulation on Increasing Efficiency in the Use of Energy Resources and Energy" published in the Official Gazette dated 27.10.2011, the necessity of using LED lamps in outdoor lighting systems such as roads, parks, and gardens is stated. According to the action code, SA-02/SH-01/E-01 of the Energy Efficiency Strategy Document covering the years 2012-2023, published on 20/2/2012, the maximum annual energy demand for lighting in new buildings will be determined. The energy resources that will meet this energy demand will be efficient and clean, the amount of CO2 emissions released into the atmosphere will be determined, and new building constructions exceeding the limit values will not be allowed [12]. An action named "Increasing Energy Efficiency in General Lighting" in the National Energy Efficiency Action Plan (NEEAP) was introduced in March 2018, which stated that the fixtures used in general lighting should be replaced with efficient fixtures. In addition, the necessity of converting sodium vapor luminaires to LED luminaires and evaluating them in terms of benefit/cost, time, and efficiency has been demonstrated [12, 13].

Regulation (EU) No 874/2012 was repealed and replaced by the Energy Labeling Regulation (EU) 2019/2015. Following rescaling of the EU energy label for lighting products in September 2021, the new labels use a scale from A (most efficient) to G (least efficient). Existing stocks with the old label will continue to be sold until March 1, 2023. Eco-design rules are mandatory for all manufacturers and importers who want to sell their lighting products in the EU. With the use of more efficient lighting products in Europe, up to 34 TWh of electricity will be saved until 2030. Thus, approximately 7 million tons of CO2 emissions will be prevented every year [14, 15]. Lighting equipment and LED lamps produced in Türkiye and entering the EU market must have passed the necessary tests under the specified regulations. The aim of this paper is to examine the EU eco-design directives specifically for lighting and to test whether LED lamps of different brands and models sold in the Turkish market are suitable for eco-design procedures. LED lamps were tested and photometric analyses were performed according to (EU) 2019/2015 Energy Labelling Regulation. The photometric values obtained as a result of the analyses were used in the energy efficiency equations specified in the Eco-design Directive and the results were compared. The study is divided into five sections. The second part discusses the situation of the LED market in Turkey. The third section explains the Eco-design Directive and energy labelling. The methods used in the study according to the energy efficiency directives are explained in the fourth section. The fifth section describes the test setup and procedures. The sixth section compares the test results. The last section presents the results and future implications.

2 LED market status in Türkiye

The manufacturing industry produces six main groups of lighting products. The first group includes lamps, which serve as light sources. The second group comprises monoblock headlamps, lighting equipment, and visual signaling equipment designed for vehicles. The third group encompasses luminaires, electrical parts, side parts, lampshades, chandeliers, sconces, spots, and projectors. The fourth group focuses on street lighting equipment. The fifth group involves portable electric lamps, torches, gas lamps, and electronic components. Lastly, the sixth group pertains to billboards and signaling equipment. Table 1 illustrates the top 10 countries from which Turkey imports LED lamps, with up to 96% of these lamps being imported from China [16].

Table 1. LED lamp imports by country [16]

Top	Country	Number	Dollars (US)	Dollars /Number
	Total	**59,719,481**	**49,935,124**	**0.84**
1	China	58,100,933	48,075,755	0.83
2	Egypt	1,112,856	538,249	0.48
3	Germany	257,609	311,779	1.21
4	Bulgaria	94,036	302,443	3.22
5	Japan	53,525	258,899	4.84
6	United Kingdom	4,689	80,359	17.14
7	Hungary	26,042	61,229	2.35
8	Taiwan	15,180	56,287	3.71
9	Italy	27,312	53,335	1.95
10	Holland	2,074	43,533	20.99

Table 2 shows the lamp export data in Türkiye between 2013-2018. Hot cathode fluorescents and other filament lamps are the most exported lamps. Although there has been a decrease in the annual total number of exports, it is observed that the number of lamps and equipment exported increased slightly in 2018. The export of LED lamps has been increasing since 2017. While the number of entrepreneurs in the electrical Lighting equipment manufacturing industry in Türkiye was 1,849 in 2010, this number reached 4,375 in 2018. While the production value was 1.46 billion TL in 2010, it reached 6.45 billion TL in 2018.

3 The EU Eco-design and energy labeling

The 2012 EU Energy Efficiency Directive promoted energy efficiency for a 20% reduction in primary energy consumption by 2020. The EU commission amended the Energy Efficiency Directive by updating its policy framework in 2018. According to this change, an energy efficiency target of at least 32.5% was determined for 2030. EU countries will each need to deliver 0.8% new energy savings for the 2021-2030 period to achieve this target. In addition, the regulations regarding the energy efficiency and environmental requirements of energy-related products entering the EU market have been determined with The EU Eco-design and Energy Labeling Directives. In 2020, the non-residential sector accounted for roughly 85% of the total electricity used for lighting. Within this sector, 53% of the consumption came from linear fluorescent lamps, 16% from high-intensity discharge lamps, and the remaining 16% from compact fluorescent lamps, halogen lamps, and LEDs. Major consumers included offices (20%), stores (15%), production areas (15%), road lighting (14%), and circulation areas such as halls, corridors, and stairs in buildings (10%). Despite a 65% increase in the installation of light sources from 2005 to 2020, electricity consumption only rose by 33%. The primary factor behind this lower electricity consumption relative to the number of installed light sources is the Eco-design Directive. Moreover, it is expected that the electricity consumption attributed to light sources will decrease by 5% in 2030 compared to 2020, primarily driven by the surge in sales of LED products. The eco-design approach strives to minimize the environmental impact of products throughout their entire life cycle.

In 2005, the Commission introduced the Eco-design Directive (2005/32/EC), establishing the initial framework. This marked a pivotal moment in the EU's Integrated Product Policy (IPP), aiming to diminish the environmental footprint of products. The Eco-design Directive, initially shaped by the demands of the consumer market, represented a supply-side instrument.

Table 2. Lamp exports in Türkiye (US Dollars)[16]

Name of the product	2013	2014	2015	2016	2017	2018
Monoblock headlight units	817,446	537,577	565,329	624,085	523,654	517,757
Halogen lamps with tungsten filament	2,868,458	3,294,888	2,072,060	1,686,158	1,720,516	2,052,749
Filament lamps (power<200W, voltage>100V)	7,113,580	6,212,665	4,485,830	2,891,092	1,821,719	1,755,412
Other lamps with filament	3,758,052	3,830,444	3,056,277	3,247,634	3,102,948	3,274,078
Hot cathode fluorescents	9,122,524	7,260,516	8,124,578	5,386,859	4,999,754	5,257,556
Mercury and sodium vapor lamps	4,705,502	4,666,773	4,900,478	4,057,118	2,764,805	2,070,711
Other discharge lamps (except ultraviolet lamps)	1,312,915	988,499	742,566	1,054,527	546,265	677,278
Arc lamps	93,008	79,892	140,313	131,713	146,884	125,701
Violet and infrared ray lamps	1,613,257	1,387,856	639,961	452,036	346,883	370,590
LED lamps					2,097,371	3,211,960
Lamp Total	31,404,742	28,259,110	24,727,392	19,531,222	18,070,799	19,313,792
Parts of glow, discharge-based electric bulbs and arc lamps	1,341,102	2,228,426	1,601,044	1,785,260	1,156,124	598,104
Lamp and Parts Total	**32,745,844**	**30,487,536**	**26,328,436**	**21,316,482**	**19,226,923**	**19,911,896**

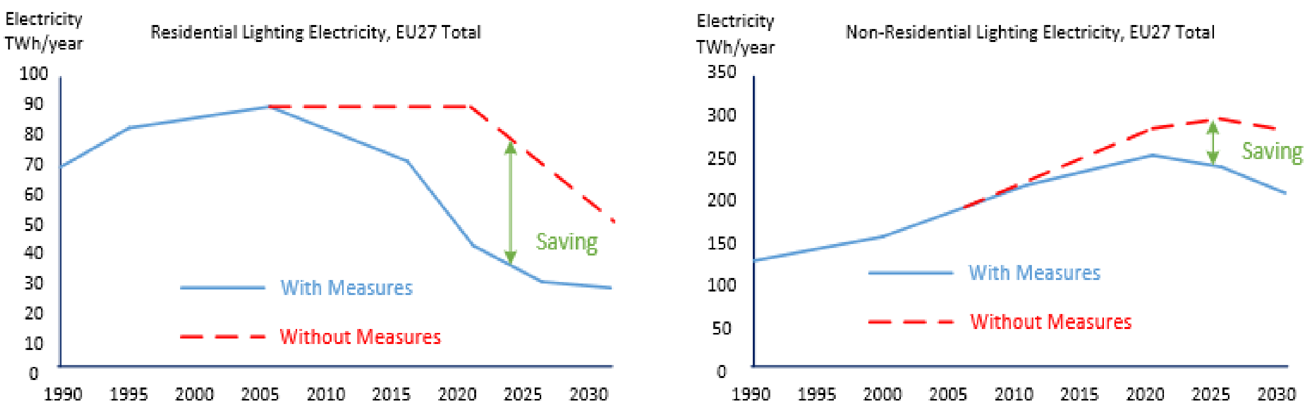


Figure 2. The annual distribution of electricity consumption for lighting in residential and non-residential areas [5]

Nevertheless, this directive's scope only addressed 31-36% of the environmental impacts of the encompassed products. It was later replaced by Framework Directive 2009/125/EC to broaden the scope to all items potentially affecting energy consumption. The Directive underwent a revision in 2020, encompassing a majority of products with the highest energy-saving potential. The selection process relied on robust and transparent methodologies to achieve optimal impact. The eco-design framework outlines general rules and conditions but does not specify product requirements. The methodology for establishing minimum requirements under the Eco-design Directive has undergone significant enhancements compared to previous directives [17]. The Eco-design Directive has established performance criteria that manufacturers must meet to place their products on the market legally. The directive covers all energy-using products sold in the commercial and industrial sectors. Energy labels, on the other hand, inform consumers about the electrical appliance's energy efficiency and electricity consumption. Thus, consumers can easily compare products with different characteristics and make a conscious purchase decision [16, 18, 19]. Lighting products are subject to EU energy labeling and eco-design requirements. According to the old regulation (EU) 874/2012, lighting products are rated from A++ (most efficient) to E (least efficient). According to the (EU) 2019/2015 new energy labeling regulation, effective from 1 September 2021, light sources are rated from A (most efficient) to G (least efficient). The sale of lighting products manufactured and labeled according to the old regulation will continue until September 1, 2023. The sale of existing stocks will not be allowed after the 2-year transition period. The EU Eco-design and Energy Labeling Directives set minimum energy efficiency standards, lamp life, and other requirements such as warm-up time, as well as encouraging the replacement of filament and halogen bulbs with more efficient lighting technologies such as LED bulbs [20].

The distribution of electricity used for lighting in the residential and non-residential areas by year is shown in Fig.2. Directives such as Eco-design and Energy Labelling, and the measures to be taken to implement them, have the potential to save an average of 50 TWh per year of electrical energy used for lighting.

4 Material and methods

All calculations used in this study were made by the requirements of the EU 2019/2015 regulation published in the Official Journal of the European Union and entered into force on 1 September 2021. First, energy efficiency calculations of ten LED lamps of different brands sold in the domestic market were made according to the 874/2012 and 2019/2015 directives. As a result of the calculations, it has been revealed whether the LED lamps comply with the new directive.

4.1 Energy efficiency requirements according to (EU) 874/2012 directive

Following the guidelines set by European Union (EU) standard 874/2012, the Energy Efficiency Index (EEI) of a model is determined by comparing its wattage, adjusted for any losses attributed to control gear, with its reference wattage. The reference power is derived from the useful luminous flux, encompassing the total flux for non-directional lamps and the flux within a 90° or 120° cone for directional lamps.

The EEI is calculated as follows:

$$EEI = \frac{P_{cor}}{P_{ref}} \quad (1)$$

$$P_{ref} = 0{,}88\sqrt{\phi} + 0{,}049\phi \quad (2)$$

$$\%E = 100(1 - EEI) \quad (3)$$

P_{cor}: nominal power (W); P_{ref}: reference power (W); Φ: total luminous flux (lm); E: % energy-saving

The energy efficiency class of lamps shall be determined on the basis of their as set out in Table 3. According to this table, the energy efficiency class of LED lamps is determined according to the energy efficiency index (EEI) value for non-directional lamps [21].

Table 3. (EU) 874/2012 Energy efficiency classes for lamps

Energy efficiency class	Energy efficiency index (EEI) for non-directional lamps	Energy efficiency index (EEI) for directional lamps
A++ (most efficient)	EEI≤0.11	EEI≤0.13
A+	0.11<EEI≤0.17	0.13<EEI≤0.18
A	0.17<EEI≤0.24	0.18<EEI≤0.40
B	0.24<EEI≤0.60	0.40<EEI≤0.95
C	0.60<EEI≤0.80	0.95<EEI≤1.20
D	0.80<EEI≤0.95	1.20<EEI≤1.75
E (least efficient)	EEI>0.95	EEI>1.75

4.2 Energy efficiency requirements according to the (EU) 2019/2015 directive

According to the (EU) 2019/2015 European Union standard, the useful luminous flux (lm) declared by the manufacturer and the power consumption values in operation should be known for calculating the total network efficiency of the lamps. For this, parameters such as declared power and useful luminous flux of LED lamps are measured, and the total network efficiency (η_{TM}) is calculated with Equation (4).

$$\eta_{TM} = \left({\phi_{use}}/{P_{on}} \right) . F_{TM} \tag{4}$$

ϕ_{use}: useful luminous flux (lm); P_{on}: declared on-mode power consumption (W); F_{TM}: efficiency factor

The efficiency factor (F_{TM}) is found from Table 4 according to the type of light source. Since LED lamps are in the group of non-directional lamps, the efficiency factor value is determined as "1" from the Table 4.

Table 4. Efficiency factor (F_TM)

Light source type	Factor F_{TM}
Non-directional (NDLS) operating on mains (MLS)	1.000
Non-directional (NDLS) not operating on mains (NMLS)	0.926
Directional (DLS) operating on mains MLS	1.176
Directional (DLS) not operating on mains (NMLS)	1.089

According to the calculated total mains efficacy (η_{TM}), the energy efficiency class of the lamp is determined according to Table 5.

Table 5. (EU) 2019/2015 Energy efficiency classes of light sources

Energy efficiency class	Total mains efficacy η_{TM} (lm/W)
A	$210 \leq \eta_{TM}$
B	$185 \leq \eta_{TM} < 210$
C	$160 \leq \eta_{TM} < 185$
D	$135 \leq \eta_{TM} < 160$
E	$110 \leq \eta_{TM} < 135$
F	$85 \leq \eta_{TM} < 110$
G	$\eta_{TM} < 85$

4.3 Test setup and procedure

In order to measure the photometric and electrical performance of commercially produced LEDs, such as energy efficiency, total luminous flux, luminous efficiency, color temperature, and wavelength (spectral region), some tests are applied to LEDs. One of them is laboratory equipment called "Integrating Sphere" or "Ulbricht Sphere," which is usually used for non-directional light sources. It is used to characterize various light sources, including integrated spheres, LEDs, and SSL products. LED's quality should be tested by checking its photometric, colorimetric and electrical parameters. According to CIE 177, CIE84, CIE-13.3, IES LM-79-19, Optical-Engineering-49-3-033602, COMMISSION DELEGATED REGULATION (EU) 2019/2015, IESNA LM-63-2 and ANSI-C78.377, it recommends to using an array spectroradiometer with an integrating sphere to test SSL products.

As a result of the measurement made with the Ulbricht Sphere, some of the parameters of the light source are:

- Luminous flux (lumen)
- Power (W)
- Total mains efficacy (lm/W)
- Correlated colour temperature (CCT) (K)
- Colour rendering index (CRI)
- Dominant wavelength (nm)
- Chromaticity coordinates (x,y)
- Power factor
- Energy efficiency classes

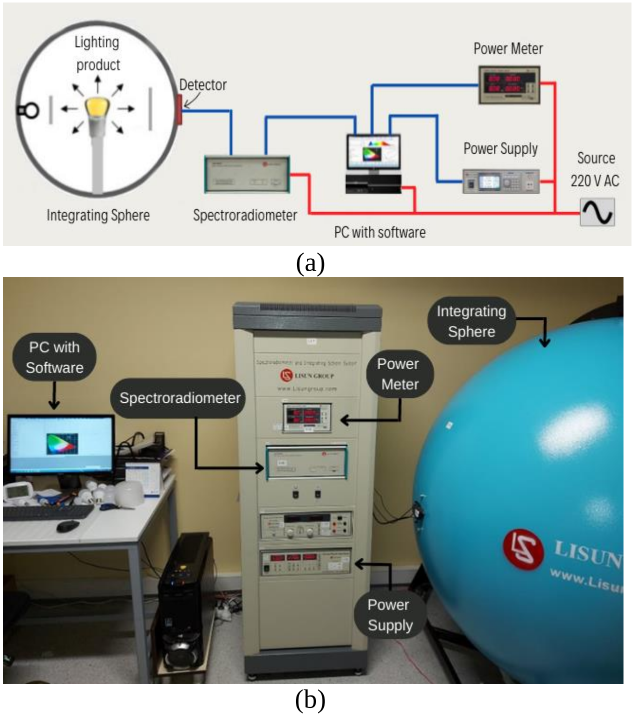


Figure 3. Test set-up block diagram (a), Test set-up built-in assembly (b)

High precision spectroradiometer (High Precision Spectroradiometer), Integrating Sphere System (LMS-9000), power analyzer, adjustable AC/DC power supply and computer were used in these measurements. The measuring setup is shown in Fig. 3. All photometric and electrical tests of the LED lamps used in the study were carried out in accordance with European Union standards with the LISUN brand LMS-9000B -Spectroradiometer Integrating Sphere System.

All photometric and electrical tests of LED lamps are made with the measurement setup prepared above. The test result report is issued by following the test procedures below.

The steps of the test procedure are as follows:

- The computer containing all electrical components and the program that will control the system is turned on (On),
- The program to control the system is run,
- The power supply is adjusted to the voltage value suitable for the operating requirement of the light source,
- The light source is placed inside the sphere using an apparatus suitable for its physical connection,
- The light source is energized and continuously for at least 30 minutes. is operated as a preheat throughout,
- At the end of the preheating period, the measurement is taken with the computer program,
- A report is obtained from the computer program with the parameters selected according to the test purpose.

(Ambient temperature should be 25°C (±0.5°C) and relative humidity 60% (±2) during the entire test period.)

An example test result report is shown in Figure 4.

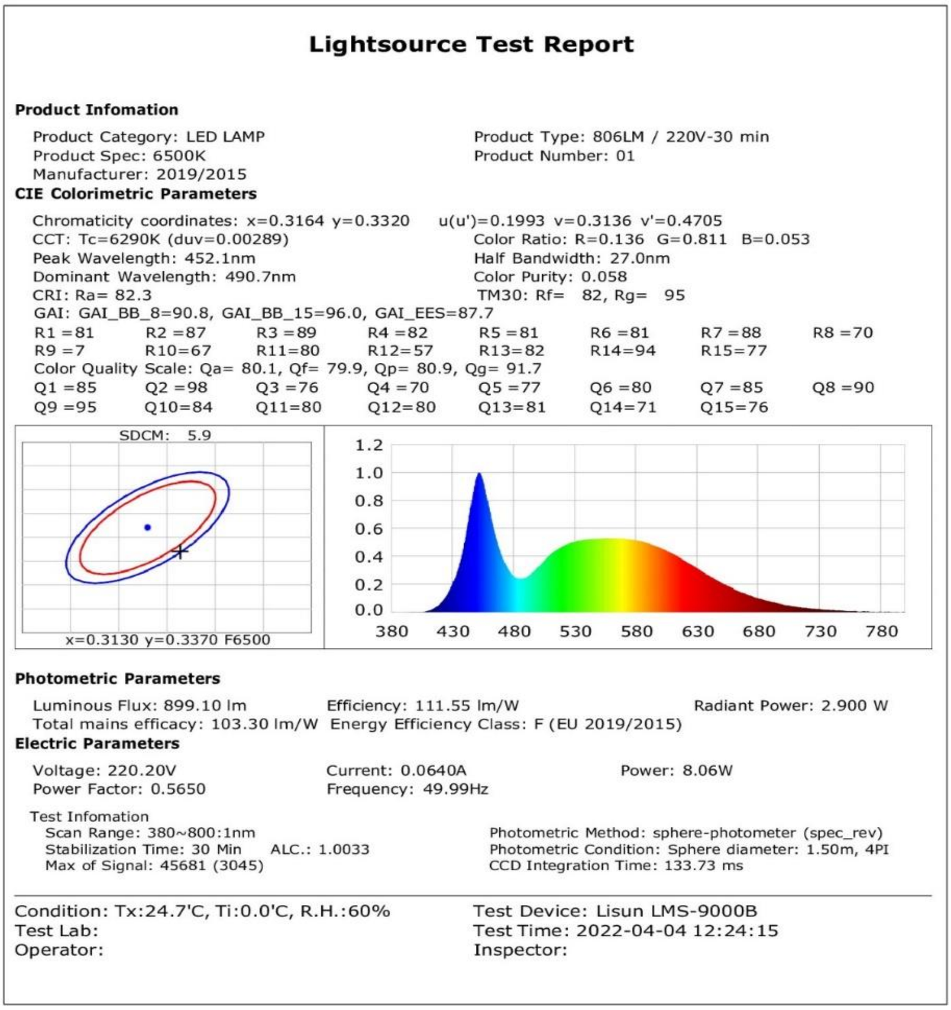
The following values are obtained as a result of the light source test report:

Colorimetric- Chromaticity coordinates, CCT, Color Ratio, Peak Wavelength, Half Bandwidth, Dominant Wavelength, Color Purity, CRI, CQS, TM-30 (Rf, Rg), Spectrum Test.

Photometric- Luminous Flux, Luminous Efficiency, Radiant Power, EEI, Energy Efficiency Class, Pupil Flux, Pupil Flux Efficiency, Pupil Factor, Cirtopic Flux, Plant Growth Lamp PAR and PPF.

Electrical- Voltage, Current, Power, Power Factor, Displacement Factor, Harmonic

LED optical maintenance test- Flux VS time, CCT VS time, CRI VS time, Power VS time, Power Factor VS time, Current VS time and Flux Efficiency VS time.


Lightsource Test Report

Product Infomation

Product Category: LED LAMP
Product Type: 806LM / 220V-30 min
Product Spec: 6500K
Product Number: 01
Manufacturer: 2019/2015

CIE Colorimetric Parameters

Chromaticity coordinates: x=0.3164 y=0.3320 u(u')=0.1993 v=0.3136 v'=0.4705
CCT: Tc=6290K (duv=0.00289)
Color Ratio: R=0.136 G=0.811 B=0.053
Peak Wavelength: 452.1nm
Half Bandwidth: 27.0nm
Dominant Wavelength: 490.7nm
Color Purity: 0.058
CRI: Ra= 82.3
TM30: Rf= 82, Rg= 95
GAI: GAI_BB_8=90.8, GAI_BB_15=96.0, GAI_EES=87.7

R1 =81	R2 =87	R3 =89	R4 =82	R5 =81	R6 =81	R7 =88	R8 =70
R9 =7	R10=67	R11=80	R12=57	R13=82	R14=94	R15=77	

Color Quality Scale: Qa= 80.1, Qf= 79.9, Qp= 80.9, Qg= 91.7

Q1 =85	Q2 =98	Q3 =76	Q4 =70	Q5 =77	Q6 =80	Q7 =85	Q8 =90
Q9 =95	Q10=84	Q11=80	Q12=80	Q13=81	Q14=71	Q15=76	

Photometric Parameters

Luminous Flux: 899.10 lm
Efficiency: 111.55 lm/W
Radiant Power: 2.900 W
Total mains efficacy: 103.30 lm/W
Energy Efficiency Class: F (EU 2019/2015)

Electric Parameters

Voltage: 220.20V
Current: 0.0640A
Power: 8.06W
Power Factor: 0.5650
Frequency: 49.99Hz

Test Infomation
Scan Range: 380~800:1nm
Photometric Method: sphere-photometer (spec_rev)
Stabilization Time: 30 Min ALC.: 1.0033
Photometric Condition: Sphere diameter: 1.50m, 4PI
Max of Signal: 45681 (3045)
CCD Integration Time: 133.73 ms

Condition: Tx:24.7'C, Ti:0.0'C, R.H.:60%
Test Device: Lisun LMS-9000B
Test Lab:
Test Time: 2022-04-04 12:24:15
Operator:
Inspector:

Figure 4. Test result example

Table 6. Declared vs. measured photometric and electrical parameters of the selected LED lamps

	DECLARED VALUES			SPHERE-PHOTOMETER MEASUREMENT						
Product Code	P_{on} (W)	**Luminous Flux** $[\emptyset]$ (lm)	**Correlated Color Temperature** (CCT) (K)	P_{cor} (W)	**Luminous Flux** $[\emptyset]$ (lm)	**CorrelatedC olor Temperature** (CCT) (K)	**Voltage** (V)	**Current** (A)	**Power Factor**	**Total mains efficacy** (η_{TM}) (lm/W)
A Brand	5	400	6500	5.04	402	6534	220.1	0.044	0.513	79.79
B Brand	6.5	525	3000	5.61	533	2949	220.1	0.047	0.538	94.91
C Brand	7	780	6500	6.41	431	6574	220.1	0.06	0.48	67.26
D Brand	7	630	6500	4.84	234	6008	220.1	0.023	0.929	48.3
E Brand	5	300	6500	4.77	274	3077	220.1	0.045	0.476	57.46
F Brand	5	350	6400	3.94	272	6322	220.1	0.034	0.526	68.94
G Brand	8	640	6500	5.71	319	6840	220.1	0.027	0.941	55.89
H Brand	8.5	806	6500	8.09	864	6564	220.1	0.065	0.558	106.82
I Brand	9	840	6500	8.31	876	6308	220.1	0.065	0.58	105.43
J Brand	9.5	820	6400	8.45	795	6216	220.1	0.07	0.541	94.03

5 Results and discussion

The photometric and electrical parameters obtained from the measurements made for ten different brands and models of LED lamps are shown in Table 6. The names of LED lamp manufacturers are reserved for commercial and legal reasons.

The test and analysis results performed according to the EU 874/2012 and EU 2019/2015 regulations are shown in Table 7.

According to the test and analysis results, it has been seen that an LED lamp with energy efficiency class A+ has F or G class energy efficiency in the new classification. According to the test results, the declared values of some LEDs significantly differ from the measurements. The reason for the inconsistency in these LEDs, which are generally considered as low-cost imported brands, should be thoroughly investigated to determine whether it stems from deficiencies in the import testing processes or from issues specific to the samples.

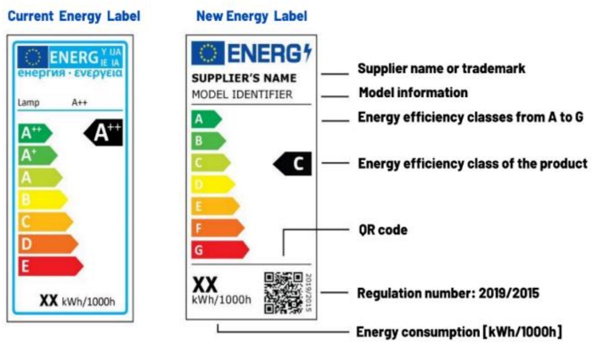


Figure 5. Current and new energy class labels for lamps

The new energy label (Figure 5) includes a QR code that links to an EU-wide database where consumers can find more detailed information about the product.

6 Conclusions

Before discussing the results, it should be noted that the low sample size in the study is due to the limited time available for working with the test system. The length of time required for the system to reach its nominal temperature and for the LEDs to stabilize has constrained our sample size. To represent the general situation, the samples were selected from among well-known imported brands, domestic products, and low-cost imported brands, focusing on low-power models intended for home use.

It is clear that the EU 2019/2015 regulations will increase the pressure on the already highly competitive lighting market. Although some brands appear to be twice as efficient as others in terms of light output per watt, they may only be ranked one level higher according to the new labeling. The reason all brands meet the efficiency requirements at the lowest level in the tests is that the EU 2019/2015 regulations do not have a minimum lm/w limit for class G. Therefore, relatively efficient products should be at least class F. Informing end users about this is important for the efficient use of energy.

While the sample size in this study may be limited, it provides valuable technical insights into the compliance of LED lamps produced in Türkiye with the latest energy labeling regulations. Moreover, this research serves as a reference point for manufacturers aspiring to establish a presence in the Turkish and EU LED lighting market, emphasizing the importance of adhering to ecodesign and energy efficiency standards to meet consumer and regulatory expectations.

Table 7. Comparison of energy classes of selected LED lamps according to according to the EU 874/2012 and EU 2019/2015 regulations

Electrical Parameters of the LED Lamps					EU 874/2012		EU 2019/2015	
Product Code	**Luminous Flux** $[\emptyset]$ (lm)	P_{on} (W)	P_{cor} (W)	**Calculated Equivalent Power** (P_{ref}) (W)	**Energy Efficiency Index** (EEI)	**Energy Efficiency Class**	**Total mains efficacy** (η_{TM}) (lm/W)	**Energy Efficiency Class**
A Brand	402	5	5.04	37	0.135	**A+**	79.8	**G**
B Brand	533	6.5	5.61	46	0.121	**A+**	95.0	**F**
C Brand	431	7	6.41	39	0.163	**A+**	67.2	**G**
D Brand	234	7	4.84	25	0.206	**A**	48.3	**G**
E Brand	274	5	4.77	28	0.170	**A**	57.4	**G**
F Brand	272	5	3.94	28	0.142	**A+**	69.0	**G**
G Brand	319	8	5.71	31	0.182	**A**	55.9	**G**
H Brand	864	8.5	8.09	68	0.119	**A+**	106.8	**F**
I Brand	876	9	8.31	69	0.120	**A+**	105.4	**F**
J Brand	795	9.5	8.45	64	0.133	**A+**	94.1	**F**

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Conflict of interest

The authors declare that there is no conflict of interest

Similarity rate (iThenticate): 15%

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