European Commission

JRC CONFERENCE AND WORKSHOP REPORT

Proceeding of the 11th International Conference on Energy Efficiency in Domestic Appliances and Lighting (EEDAL'21)

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2023

EEDAL
Energy Efficiency in Domestic Appliances and Lighting

Joint Research Centre

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JRC132721

PDF ISBN 978-92-76-99908-9 doi:10.2760/356891 KJ-07-23-093-EN-N

Luxembourg: Publications Office of the European Union, 2023

How to cite this report: *Proceeding of the 11th International Conference on Energy Efficiency in Domestic Appliances and Lighting (EEDAL '21)*, Bertoldi, P. (ed.), Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/356891, JRC132721.

Contents

Abstract

This book contains the papers presented at the eleventh international conference on Energy Efficiency in Domestic Appliances and Lighting, EEDAL'22 organised in Toulouse, France, on 1-3 June 2022 by the European Commission Joint Research Centre and the University of Toulouse III - . Paul Sabatier. This major international conference has been very successful in attracting an international community of stakeholders consumption (including manufacturers, consumers, governments, international organisations, academia and experts) dealing with residential appliances, equipment, metering, lighting, residential building energy consumption to discuss the progress achieved in technologies, behavioural aspects and policies, the strategies that need to be implemented to further progress this important work. Potential readers, who may benefit from this book, include researchers, engineers, policymakers, and all those who can influence the design, selection, application, and operation of electrical appliances and residential buildings.

1 Introduction

This book contains the Proceedings of the eleventh international conference on Energy Efficiency in Domestic Appliances and Lighting EEDAL'22 organised in Toulouse, France, on 1-3 June 2022 by the European Commission Joint Research Centre and the University of Toulouse III - . Paul Sabatier.. The international community of stakeholders dealing with residential equipment, metering and lighting (manufacturers, retailers, consumers, governments, utilities, international organisations and agencies, academia and experts, etc.) have already gathered ten times at the International Conference on Energy Efficiency in Domestic Appliances and Lighting (EEDAL) (Florence 1997, Naples 2000, Turin 2003, London 2006, Berlin 2009, Copenhagen 2011, Coimbra 2013, Lucerne 2015, Irvine 2017, Jinan, 2019). EEDAL'22 has provide a unique forum to discuss and debate the latest developments in energy and environmental impact of residential appliances and lighting, heating and cooling equipment, electronics, smart appliances, smart meters, consumer behaviour, the policies and programmes both adopted and planned, includinh their evaluation.

EEDAL will also address the technical and commercial advances in the dissemination and penetration of technologies and solutions. The three-day conference included plenary sessions where key representatives of governments and international organisations, manufacturers utilities, and academia presented their views and programmes to advance energy efficiency in residential appliances and lighting, for example, through international co-operation on product information and eco-design requirements.

Scientific parallel sessions on specific themes and topics allowed more detailed, technical and scientific presentation, in-depth discussions among participants. The EEDAL '22 conference papers presented in the scientific session included in the current Proceedings covered the following topics:

1. Policies, Standards and Labels

2. Market Surveillance and Testing

3. Focus on Developing Countries

4. Heating and Cooling

5. Buildings

6. Behaviour

7. Monitoring

8. Demand Response and Renewable Energies

9. Appliances and Lighting

Performance from SSL Lamps used in the Brazilian Residential Sector

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Abstract

Lamps with solid state Lighting technology (SSL), base type (E-27) have shown reduced useful life values, according to users' declarations. The useful life (median) was obtained from an experiment, sample with eight types of WLEDi lamps, six different brands acquired in the Brazilian consumer market. The experiment was carried out under ambient temperature. The light output was sampled throughout the experiment by using a built-in integrator photometer and reference lamps. Different patterns of light depreciation were observed. The median of the sample was evaluated at 22 % of the nominal value and that appears on the package (25 kh) of all brands of electric LED lamp, base E-27, the type that was used in the first long-term experiment, without any extra thermal or electrical stress and which ended with a total energizing period of 6.99 kh. Spectral survey of emission from lamps and transmission factor of diffusers were carried out and are also provided. The result revealed a difference between the estimated value based on the performance from sampling carried out and the declared value in a lamp that contains a national visual identification (label) of product conformity (safety and performance). The methodology presented is simple and can help to identify, within the lamp product commercialization sector and the Brazilian lighting sector, some type of non-conforming product. A second sample is being obtained, and results of initial condition assessments that have already been carried out and that are being conducted and some selected associated subjects are presented and discussed.

Keywords: SSL Technology, Inorganic White Lighting Emitting Diode - WLEDi Lamp (LED Lamp), Standard, Developing Countries, Residential Lighting, Market Surveillance, End of Product Useful Life.

Introduction

The Brazilian residential sector had electricity consumption in 2021 of 151 TWh, which represents 30.15 % of the total electricity consumption [1], with an average monthly consumption of 159.73 kWh per household [2]. According to the same survey of possession and habits [2] it was found that each Brazilian household has an average of 6.50 light bulbs, 8.5 % incandescent, 57.5 % fluorescent, 32.3 % SSL (LED), and about 1.5 % from other technologies. In the year 2022, lamps with a luminous flux of 803 to 810 lm were acquired at points of sale in Brazil for an average price of US$ 2.01 (reference April, 2022).

The conventional incandescent lamp, in the year 2016, was banned from the market in Brazil. Currently, the user with an Edison lamp holder (E-27 base) has the option: to use the single base fluorescent lamp (CFL) or the Solid State Lighting technology (SSL: WLEDi). Local users have provided faulty lamps for evaluation and reported a very short lifespan for WLEDi lamps (inorganic white LED) with base type E-27. The penetration in the Brazilian market of SSL is effective and the knowledge available to the consumer about the reliability and effects associated with inorganic LED products to provide white light is reduced. On the product packaging, there is, highlighted a kind of label called: "Energy LED lamp"; "safety and performance", in addition to data identifying the certification process, the Brazilian Label Program - PBE (registration number, certifier), luminous flux, nominal electrical power, and luminous efficiency. The manufacturing date is also considered relevant product information. The three parameters mentioned above, which are accessed on the PBE label, whose format can be observed in a regulation model for the lighting sector in different countries. Taking the European model [3], there are two groups of requirements: product information (rated power, luminous flux, luminous efficiency, the statement on light output adjustment or "dimming", correlated color temperature) and optional information: equivalence, in power, with another conventional light source such as incandescent, the lifetime statement claim (here relevant note is made: the lifetime claim is optional, must be evidence-based, and due to the long-expected lifetime of LED lamps, termed efficient, the service life requirement can demand quite long periods for verification, depending on the application applied and, consequently, it is not considered for practical purpose. The present article discusses some of the parameters mentioned above, considering the expansion of the requirements contained in the PBE label based on experimental activities results. In the first long-term experiment, carried out with six different brands of WLEDi lamps, base type E-27, acquired in the Brazilian market to reproduce the situation of a typical consumer of the residential sector, considered the necessary financial resources to purchase a set of WLEDi lamps with an Edison base (E - 27) and expectation of accessing the median life of the sample. It was an experiment to collaborate with the training of human resources (academic). In the experiment beyond the median useful life, the luminous depreciation of sample elements was provided too. The reliability of the sample was considered for the elapsed period from the experiment until we had the sample in operation (or without showing performance: abrupt fail or L_{70}). A second experiment was started this year (2021), which is also expected to be carried out after the lamps had been subjected to data collection on the initial spectral emission ("zero hours"). Figure 1 shows a radiant Spectral Power Distribution (SPD) for a WLEDi tubular and one referential, incandescent lamp (on the right side).

Figure 1. Spectral Power Distribution (SPD) survey result for the light output of a WLEDi lamp, type G-13 base (at the left side), and for an incandescent lamp (carried out in May, 2017).

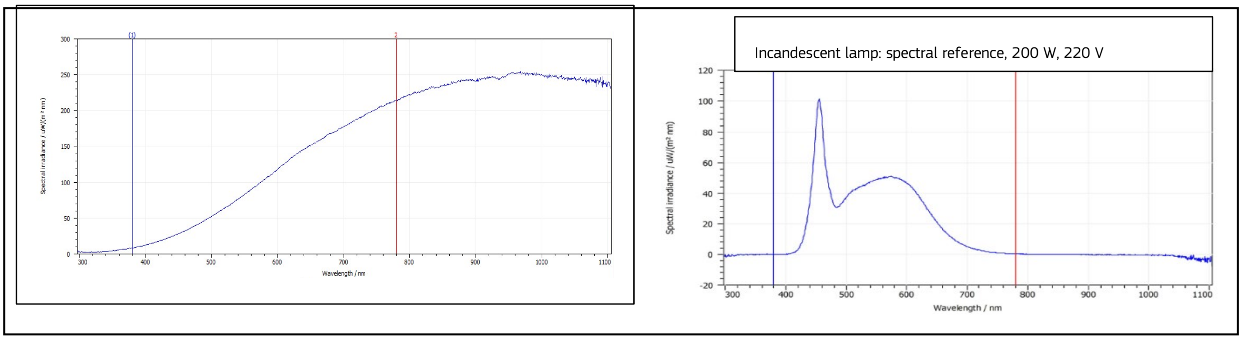


Figure 1 presents two vertical lines that delimit the so-called visible band of the electromagnetic radiation spectrum. The spectrometer used in both samples has an Instrument Systems brand, with the software called SpecWin Pro, version 3.1.1.1822, which allows the processing of spectral irradiance records with a step smaller than 1 nm. The number of brands of lamps in the sample for the second experiment is still being expanded, initially, thirty-five lamps and sixteen different brands of WLEDi lamps, base type E-27, were acquired in the Brazilian market, whose initial results were presented in an important Symposium of the lighting sector in Spain [4]. Currently, the enlarged sample is formed by forty-five lamps and eighteen brands of WLEDi lamps, now including lamps with base type G-13 (tubular). It is believed that the incorporation of as many different brands as possible can better represent groups of products in the Brazilian market. A second sampling was carried out with E-27 lamps (previously sampled), at the IEE laboratory with two G-13 (tubular LED), one CFL (Compact Fluorescent Lamp), and one incandescent lamp, to investigate the results and evaluate initial parameters and instruments performance. The results will be analyzed concerning nominal values declared on the product's body or packaging and sampled with other types of equipment with the brand Xitron and Yokogawa - YEW. The use of different instruments is intended to verify the measurement procedures used and also seeks to increase the reliability of the experimental results, in particular, harmonic distortion of the input electrical current (THDi) and power factor (PF) values. With the numerical results of some sampled lamps, provided by the laboratories of the Institute of Energy and Environment of the University of São Paulo (IEE-USP), procedures will be collated and the determination of the displacement factor (power factor of the fundamental component [5], 60 Hz) will be sought. A second parameter related to the WLEDi lamp and the power quality, in addition to the harmonic components, is the flicker for which samplings are intended after deepening and establishing the methodology. The theme is considered in the literature [6, 7, 8]. The effects of blue light on human health and possible impacts on the environment arising from the expansion of the use of SSL technology are other relevant themes for future development.

Objective

The performance of some types of lamps with SSL technology used for general lighting environments in Brazil differs from the related information contained in the product packaging. The declared useful life (L_{70}) of 25 kh, on the packaging of all products accessed, is a parameter considered relevant and that has not occurred either with a light bulb or for a sample, even considering the information like the median useful life of the sample. The hypothesis put forward is that the Brazilian market of lamps with SSL technology (LED, E-27) has products that are still quite heterogeneous, with a portion considered significant not meeting minimum technical quality requirements. The present situation suggests an investigation started. This article presents and discussed the results of the first long-term experiment carried out in the period from Dec., 2018 to Nov., 2019. Also, the initial results of the second experiment started in Jan., 2021 on the initial characteristics of lamps. According to availability and local particular prescriptions, having been conducted at the Laboratory of the Energy and Environment Institute - IEE - USP, with more sample range of WLEDi, E-27, lamps purchased at the Brazilian market. The sample has been expanded, both in brand types and in the number of proof bodies. For the second intended long-term experiment the sample was formed with 35 lamps from two classes of products, one called world and another local brand, which were considered nominal electrical power from 4.5 W to 40 W, nominal correlated color temperature (Tcp) in the 3000 K to 6500 K range. A second experimental sampling was carried out, in Nov., 2021, with five WLEDi, E-27 bulbs (already sampled previously), two G-13 base type lamps; one incandescent, and one CFL for analysis of the measurements records, statistics calculations performed are also presented. The occurrence of a possible change in the configuration of YEW equipment during part of the sampling period and estimation for the displacement factor (power factor of the fundamental component of five lamps powered at 127 V, 60 Hz) are indicated and described. To evaluate the plastic material that integrates the diffuser of the lamp, a third experiment was carried out on the transmission factor of the diffuser, which has a direct impact on the luminous efficiency of the product. Labeling and technical standards (including the topic of maximum temperature on the E-27 lamp body) are relevant topics that are considered based on the literature already accessed and experimental data collected.

Methodology

The experimental methodology was used to obtain initial characteristics such as light output from proof bodies or sample elements, relevant electrical parameters including power, electrical current, and voltage, harmonic components, power factor; light output, temperature, and median life. The bibliographic survey was carried out to search for references, in particular for the topic of labeling, and technical standards. The position of other researchers, as well as data published by another laboratory or country, is considered. Concern that was resolved from the literature collected, how the residential sector has been considered by agents in the academic world.

The first long term experiment

The report is on the long-term experiment (≥ 6000 h) conducted with WLEDi lamps purchased in the Brazilian market. The sample used is representative of lamps with SSL technology, Edison base type (E-27). Six different brands were used (Black & Decker, Brilia, FLC, Galaxy, Kian, and OUROLUX), whose purchase price was considered accessible to the typical consumer in the Brazilian residential sector. The long-term experiment was conducted at IEE-USP, in a place with high ceilings (Electrical Machines Laboratory, building "I"). During the long-term test period, each lamp was mounted on support equipment that is provided with an electromechanical "hour meter" (non-volatile recorder), several lamp holders (the test rack), and electrically connected to a stabilized voltage source. The lamps were energized at a nominal value of 225 V, in the pendant position, with the base up, and under the ambient temperature. A separation of two lamp holders was adopted between lamps and aimed to minimize heat by mutually irradiating contiguous samples. Switching occurs during the sampling process when each lamp was removed from the test site and transferred to the measurement circuit and by the use of an integrator photometer, also when an eventual shutdown of the electric source occurred due to an unforeseen outage of the external network. No additional switching regime was imposed on lamps, E-27 (test body). After each specimen was removed from the rack, it was installed and energized inside the integrator photometer (period without energization: approx. 30-45 seconds), the light output reading was performed after a set period of five minutes. This was established after verification, concerning the value read after 20 minutes, and for the use of one reference lamp (# 9), when a difference or relative deviation of 1.6 % was verified. Records from three reference lamps were used, and data collection occurred at least ten times in the period considered from 1030 hours to 4473 hours of testing. The relative light output (concerning each reference lamp) was set at 100 % for the light output obtained at 1030 hours. This is due to the behavior observed in the period before 1030 hours, when more than one type of lamp had a maximum, value of light output. A curve (second degree) was used to adjust each set of points and, when necessary, it was obtained a mean of three values of the points at which the depreciation data curve intersects the 70 % light output line (or 30 % reduction concerning the light output obtained at 1030 hours).

The median useful life of the sample.

The median useful life of the sample was determined and is presented for three different conditions used here, namely: a) when half of the entire sample failed, catastrophically (it stopped emitting light);

b) when half of the entire sample has failed, in condition L_{70} (mixed, a catastrophic failure or no light emission); c) when it failed half of the entire sample plus one lamp (lamp # 7, 9 W went out), and not be considered the initial failure (# 8, 12 W, with 1407 h); remaining lamp brand # 3, # 5 and # 6. The mean was determined from the three determined median useful life values indicated above and the associated statistical parameters.

WLEDi lamp spectral emission and incandescent reference

Three lamps had their spectral emission (SPD) sampled using the Luzchem brand spectrometer, model SPR-03, series HR4C2217 (on loan from the IAG-USP). The input signal was collected by using a semi-sphere sensor with an internal PTFE coating coupled to the equipment by an optical fiber. To have a reference in the procedure, an incandescent lamp was used. This fourth sampling is important both to verify the response of the set and for future use if the same procedure needs to be repeated. The change in the emission spectrum is a characteristic of SSL technology, which changes throughout life, as reported in the literature.

Light transmission factor and SPD of the diffuser removed from WLEDi lamps

The bulb transmission factor was determined by measuring it with an integration photometer, using the lamp itself as a light source, and the reading of the light output of the complete lamp, after energizing, was taken when five minutes stabilization defined period had elapsed. The second reading was taken after removing the diffuser. The light output was sampled over a period longer than five minutes, previously, to measure the deviation due to the truncation procedure used. For the radiometric survey, a spectrophotometer was used at the Macromolecules Lab. of the Dept. PMT-EPUSP. The diffuser removed from the lamp body was installed next to the light output window of the spectrophotometer, whose survey was carried out by the equipment in a step of approximately 1 nm (operational condition of the equipment). Each diffuser was mounted and adjusted with the concave side (outer face of the diffuser) juxtaposed on the output window of the primary light source of a Varian brand spectrophotometer, model Cary 50 conc UV-Vis. Sampling was carried out for a diffuser removed from a WLEDi lamp and wavelength range (200 to 800) nm, with the "baseline" (equipment proprietary software) being adjusted for the condition without a sample from the sample compartment filled with only air of the environment. The condition of 100 % of the light transmission factor was fixed, arbitrarily, at 800 nm.

Label for the E-27 lamp (Lamp label) and road lighting luminaire in Brazil

The Brazilian consumer of WLEDi lamps, when examining the packaging, before making the purchase decision, will be able to see a type of label (INMETRO - PNE certification), whose edges are blue. This is called the National Energy Conservation Label - ENCE, in this case for LED lamps. Currently, there is a second type of "quality" label for street light sources. They contain information established, a priori, as a service by Product Certification Bodies - OCP (https://www.gov.br/inmetro/pt-br/acesso-a-informacao/perguntas-frequent/accreditation/certification-bodies-of-ocp-products) and INMETRO. Most labels are for lamp and luminaries' safety and performance certification. It can be understood as an element that allows the consumer to analyze product characteristics and make faster comparisons between different brands. This article considers the topic of labeling due to our understanding that it is an important instrument and can be improved with a central focus both on the consumer and on the final use of electricity.

Technical standard document (norm) analysis

A labeling program, in short, needs to be supported by a robust productive sector in the country, in proven local SSL metrological capacity, at least with open auditable procedures and technical standards. Thus, considering the assumptions raised true, the need to consider subjects on the technical standards was identified in this article. A brief report on the Brazilian sector is provided and a normative document and country are used to carry out an analysis considered pertinent. A suggestion for the Brazilian technical standard new projects is presented. The very important question formulated is about the necessity of limitation of the maximum temperature on the outside part of the WLEDi lamp body, E-27, this subject is considered and experimental data on the maximum temperature sampled by image procedure is presented.

The second experiment (with an expanded sample)

For the second intended long-term experiment, the sample is being expanded, both in brands and in the number of lamps. Some metrological activities were carried out for the second experiment and data are presented and discussed. In the second experiment, for the formation of the sample, two classes of products were considered, in theory, "brands considered worldwide" and local brands. In terms of nominal electrical power for stratification, 25 W was used (below and from this value). The initial part of the second experiment was conducted at 127 V, the lower-rated voltage value shown in the product catalog, and in the second part the characteristics of the sample when under 220 V were considered, usually the other rated electrical voltage value displayed on the lamp packaging, as well as the nominal life (L_{70}) of 25 thousand hours. The time settling for each lamp in the measurement procedure, before reading the instrument, was estimated to occur in a typical period of 55 minutes (for 0,5 % maximum variation, IESNA LM-79) which is considered to be too long. The so-called "burn-in" at lamp assembly locations with SSL technology has been considered the period that the WLEDi lamp remains energized after assembly has been completed. In the case of testing, "aging" is the period that the test body needs to operate under rated voltage before each measurement procedure can be performed. A brief literature review on key topics like this one is also presented and discussed.

The luminous efficiency of lamps from the Brazilian market

Luminous efficiency is a parameter present in the label of conformity that all WLEDi lamp needs to have to be at the points of sale. Processed data from measurements performed in the labs. of the IEE-USP are presented. The data for 35 test bodies was published in 2021 [4]. The averages (and standard error), for two energization voltage conditions (127 V and 220 V), maximum and minimum values, and range (max. - min.) of a sample containing 14 different brands, and range of (4.5 to 40) W. Similar parameter data from the European/Global market was accessed and considerations are presented.

THDi and Power Factor (PF and PF_1)

The expansion of the use of a light source other than incandescent, with a focus on increasing the efficiency in the use of electrical energy, motivated studies on the impact that the presence of sources with greater light efficiency can have mainly on parameters addressed in this part of this article. Initial characteristic measurements were sampled, at the power quality lab. of the IEE-USP, as relevant electrical parameters, including harmonics and PF with the ELSPEC brand equipment, model G4500 with five WLEDi lamps, 9 W, E-27, and PF > 0.70. For further analysis, given that they had already been sampled at another lab. (XITRON and YOKOGAWA, model WT3000), comprising a sample of 35 lamps. In the present opportunity, at the IEE-USP power quality lab., two tubular WLEDi, 9 W, base G-13, 60 cm, an incandescent lamp, and a CFL were included, intended to be used as a reference for metrological ballast and possible repetitions of the experiment conducted in different labs.

Light bulbs, electricity in the Brazilian residential sector

Data on the number of installed lamps and other data from the Brazilian domestic sector were also collected and presented.

Results

The first long term experiment (from Dec., 2018 to Nov., 2019, result)

The experiment with samples of WLEDi lamps purchased in the local market started on Dec. 17, 2018, and ended on Nov. 07, 2019 (total energization: 6991.4 hours). The instants of abrupt failures observed throughout the experiment were registered, which is related to failure (when the lamp permanently interrupted the emission of light). Luminous depreciation is other data obtained relating to failure due to a 30 % light output reduction. In the experiment, due to the different behaviors, the 100 % instant of the light output was considered at 1030 hours from the initial energization which occurred on Dec. 17, 2018.

Long-term experiment: the first 815 h (result).

For the first long-term experiment, lamps with the brands: Black & Decker, Brilia, FLC, Galaxy, Kian, Ourolux, and four different nominal powers were used: (7, 8, 9, and 12) W. The light output for each lamp was recorded throughout the experiment; luminous depreciation was determined and recorded. For the interval of the first 815 h the behavior was estimated using curve fitting, see Figure 2.

Figure 2. Results for the relative (ref. lamp # 9) light output of WLEDi lamps, base type E-27, during the first 815 h, at the first long-term experiment, sample with six different brands [9].

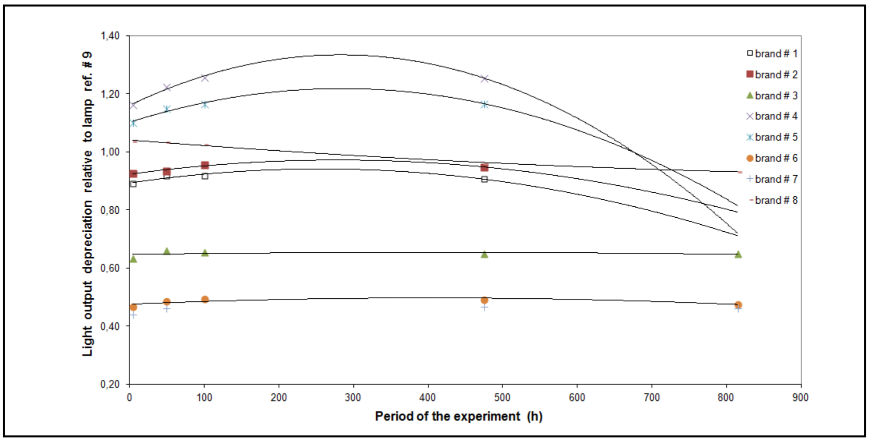


Figure 2 revealed four different behaviors for light output over the period considered. In the case of lamps # 3, # 6, and # 7, it was observed that the first result presented a slightly lower value than the other values that are considered, have reduced or little significant depreciation.

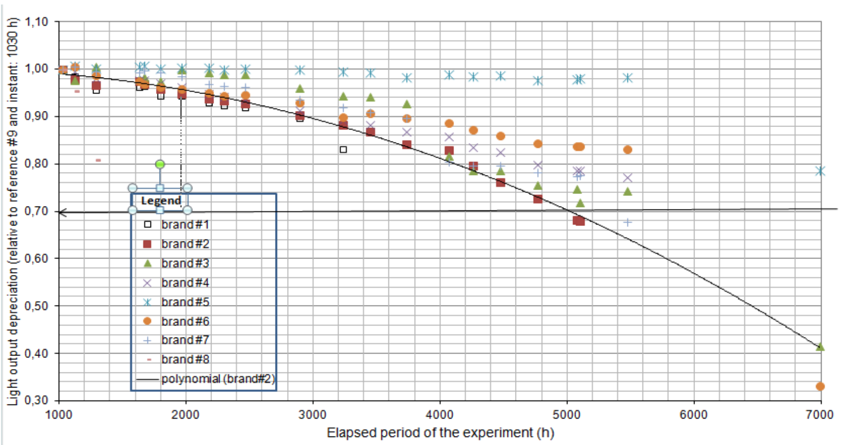
The depreciation results for the light output of lamps #1 and #2; #4 and #5 were adjusted by parabolic curves (second degree), and in the case of the last two lamps/brands, the depreciation rate was higher after the maximum region. Bulbs # 6 (7 W); # 7 (9 W), and # 8 (12 W) are from the same brand/distributor.

The question that arises: which instant should be used or considered as an initial? The publication LM 54 [10] advocates the need for seasoning for 100 h fluorescent lamps and the SSL technology (LED) there is no fixed period for seasoning "(LED). Season as recommended by the manufacturer".

Relative luminous depreciation (result).

The light output temporal variation (luminous depreciation) from each lamp brand was obtained, based on three references (lamps that were energized only when the procedure for measuring the specimens was carried out). After calculating relative luminous depreciation, to reference # 9 and the instant: 1030 h, the data were plotted along the elapsed period of the experiment (h) and are presented in Figure 3.

Figure 3. Relative luminous depreciation of sample lamps concerning the reference lamp (# 9) and defined reference instant 1030 h, from the first long-term test (Dec., 2018 to Nov., 2019).



In Figure 3 there is a horizontal line drawn for 30% depreciation (concerning 1030 h), that by definition is the L_{70} limit. The curve was also fitted (by Excel software), second degree polynomial only for lamp brand luminous depreciation data with mark # 2. The intersection point between the fitted curve and the horizontal line (L_{70}) defines the time of failure for the depreciation lamp brand identified.

The median useful life of the sample (result).

The median useful life of a sample containing six different brands of lamps was estimated for three situations considered and values as follows: a) (5521 ± 22) h, when half of the entire sample failed, catastrophically (it stopped emitting light).

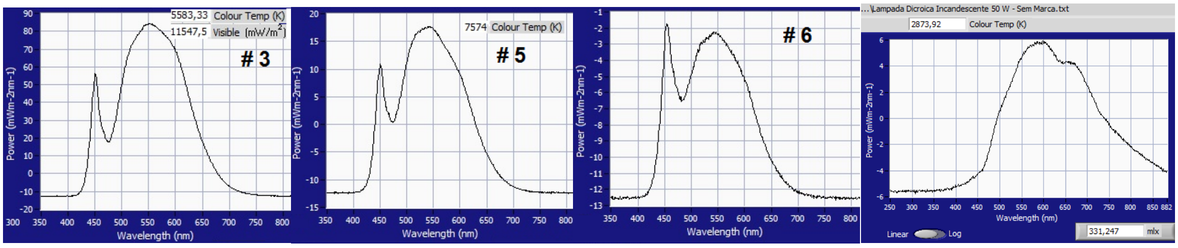
Note: The deviation was calculated as being half of the interval between two successive observations, whose second situation revealed that the failure occurred; b) 5400 h, when half of the entire sample failed, in condition L_{70} or mixed, with catastrophic failure (no light-emitting); c) 5930 h, when it failed (turned out at lamp # 7, 9 W) and the initial failure was not considered (# 8, 12 W, with 1407 h) the lamp with marks # 3 # 5 and # 6 (were emitting light).

The average median life of the sample was calculated as (5.62 ± 0.16) kh (it includes ± standard error), with a relative deviation value of 3 %, the calculation was performed using the three median life values as presented above. This represents only 22 % of the rated life as it is fixed on all WLEDi lamp packages purchased from the Brazilian market and used for the first long-term experiment (25 kh).

WLEDi lamp spectral emission and incandescent reference (result)

Three lamps had their spectral emission (SPD) sampled using a spectrometer. Even with the use of light input in a semi-sphere, the relative position between the light input from the sensor and the source can vary and, consequently, responses with different intensities and spectra can occur. To try to minimize this, an incandescent-type lamp with a dichroic reflector was used as a reference. The emission spectrum (SPD) of three brands of WLEDi lamps, base type E-27, # 3, # 5, and # 6 after 6992 hours of operation (long term experiment) and of an incandescent source are shown in Figure 4.

Figure 4. Results of SPD of WLEDi lamps, base type E-27, # 3, # 5, and # 6 (from left to right) after 6992 h, from the long-term experiment; on the right side, the incandescent source. Source: authors; Luzchem brand equipment with PTFE detector head as the light integrator.



The correlated color temperature (Tcp); the Spectral irradiance and illuminance are results from processing by the proprietary software of the spectral radiometer equipment, Luzchem brand, and model SPR-03 (HR4C2217 series) was used.

Light transmission factor and SPD of the diffuser removed from WLEDi lamps (result)

After removing the diffuser, the lamp was installed and energized inside the integrator photometer, it was not turned off and a second reading was taken. Thus, the variation can be considered negligible. The light transmission factor or light efficiency of the diffuser, considering reading values from the four minutes since the lamp was transferred from the test frame and the energization into the integrator photometer, resulted in an average (and standard error) of (82.7 ± 0.1) % for the lamp identified by # 13 and (82.4 ± 0.2) % for one with # 14. Approximately 17-18 % of the light produced by LED devices does not pass through the lamp's diffuser. The spectral transmission factor of four WLEDi lamps based on Edison type (E-27), two nominal powers, both without prior use (0 h), and a lamp that had a catastrophic failure (with 1407 h) was sampled in the spectral band (200 to 800) nm are shown in Figure 5.

Figure 5. Relative spectral transmission factor for the WLEDi lamp diffuser (9 W and 12 W; base type E-27), without use (0 h) and after 1407 h after the catastrophic failure occurred.

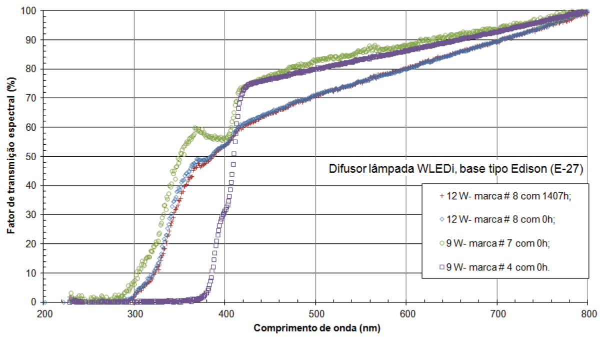


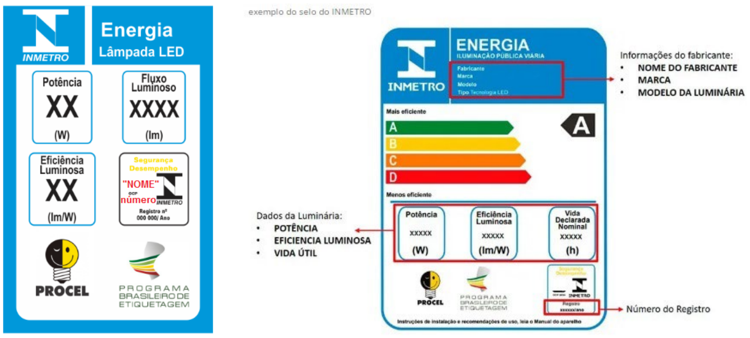
Figure 5 reveals possible depreciation, however, very few signs of the type (brand) # 8 lamp after 1407 h of use at the experiment and concerning another similar lamp, in the non-usage condition (zero hours). This result differs from the literature, acrylic diffuser (PMMA), which reveals appreciable attenuation above 400 nm and after 2000 h of testing [11]. The comparison between transmittance values at a given wavelength also suggests that they are quite different diffusers, with different materials in the composition (evaluated in this article and from the literature [11]).

In the city of São Paulo, ref. Dec., 2021, values (R$/kg) were obtained from a "walking scrap dealer" for metals: 0.8 Iron; 4 Aluminum; 40 Copper (clean). For plastics, similar information was not obtained due to the justification that it is necessary to identify and separate this type of material.

Label for the lamp (Lamp label) and road lighting luminaire in Brazil (result)

In the Brazilian market, LED lamps, since 2018, to be sold to the final consumer, need to have the INMETRO seal and respective certification, as established by INMETRO Ordinance nº 144-2015 [12]. Figure 6 shows, on the right, the seal (National Energy Conservation Label - ENCE) for LED lamps, and on the left, the seal for public street lighting, and the seals have different formats.

Figure 6. Brazilian label relating to safety and performance certification of LED lamps (on the left side) and for street lighting (on the right). <u>Source:</u> left, adapted from [13]; and the other from [14].



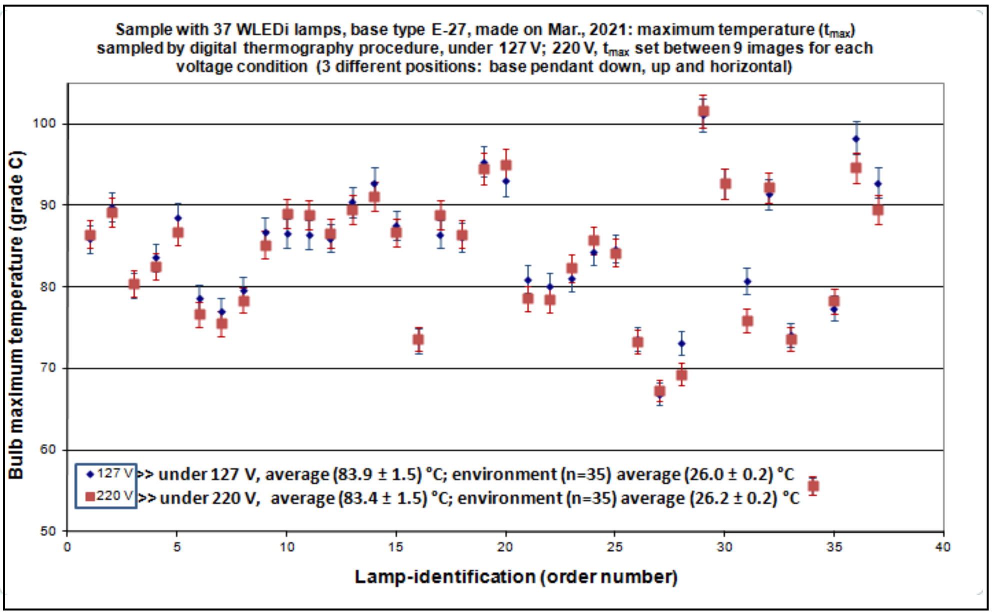
The example of a Brazilian label adopted for street lighting sources is similar to the first European label model. The research from the University of Coimbra points out that "the motivation of the Brazilian label system is based on two main factors: competitiveness and energy-saving and that the objective of the Brazilian Program for Energy Labeling (PBE) seeks to influence consumers to buy more appliances efficient ways to stimulate the competitiveness of the industry" [15]. Currently, the industrial sector of general-purpose electric light sources (base types E-27 and G-13) is no longer established in the country as a manufacturer, the assembler designation better reflects the practices that can be observed today. This article seeks to consider the topic of light sources label from the point of view of the consumer and the final use of energy.

Technical standard document analysis (result)

A technical standard is a basic instrument in any labeling program. It will enable the elaboration of procedures, which will allow technical documents such as reports from specimen characteristics. In Brazil, society's participation in national public consultation processes has evolved, going beyond the members of the Study Commission (CE), however, fluctuates a lot when considering the contributions registered in the ABNT system. For the international scenario and until the year 2015, considerations set by the Turkish academic sector were accessed [16]. The authors grouped the normative documents, mostly North American, into two groups, namely: a) Standards for the standardization of LED-type device measurement and recommendations, which brought together four documents, one of which is international, CIE and "LED Lamp and Luminaire Measurement Standards and Recommendations" which brought together four North American documents [16]. Only the CIE (2007) document is kept, all the other seven North American documents have an updated edition (IES LM-85-20, IES LM-80-20, IES TM-21-19; ANSI NEMA C78,377: 2017, IES LM-79-19, IES LM-84-20 and IES TM-28-20. Also, "The most important parameter that determines the performance of both the LED light source and the luminaries is the temperature" [16]. In Brazil, updates to the local normative document backed by an international standard (IEC) are taking place. The process is based on the Portuguese version of the IEC document chosen as of interest. For the ABNT COBEI Study Commission (SC), documents are made available that include a basic text.

In December, 2021, the (SC) started working as the basic text: project ABNT-CB-003 PROJECT 003:034.001-150 (IEC 62717; ABNT NBR IEC 62717) - LED modules for lighting in general - Performance requirements (53p.) [17], which is predicted to be identical to IEC 62717:2014 + AMD1:2015 + AMD2:2019" [18], the last edition of the considered IEC document. It is a normative document important and "new" in Brazil. The IEC PAS 62717, 2011, equivalent in Pakistan (PS: _5253-2017, ICS: 29.140.30), under the title LED MODULES FOR GENERAL LIGHTING- PERFORMANCE REQUIREMENTS was published in the year 2017 [19]. It was noted that the Pakistan standard was formulated based on IEC 62717, 2011 "LED Modules for General Lighting - Performance Requirements", it includes Amendment n.1 issued in September 2015 and incorporates modifications for the local conditions such as a modified electrical voltage range, from 80 % to 106 %; also the ambient air temperature modified to -10 °C to 50 °C; the inclusion of the provision of Surge Protection Device (SPD); and an Annex O designed to meet local requirements was verified for SSL technology: - power factor > 0.5; provision of overvoltage protection device (which compliance is recommended); 80 lm/W luminous efficiencies for bulb and tube LED lamp; 60 lm/W for panels and directional sources (lower hemisphere); and "up to 50 lm/W and above" for projectors and lights for road lighting. The first international version of the normative document, IEC PAS 62717, 2011, (Publicly Available Specifications; pre-standard) was a pre-standard that was canceled and replaced in Dec., 2014. The definitive version was published as IEC 62717:2014. That version introduced several changes to the "pre-standard (the year 2011)", two of which, due to their relevance, are presented and commented on below: - for electrical characteristics, the seasoning period can be chosen as 500 h; - for formatting photometric data files, reference is made to IEC 62722-1 (Sep., 2014). The IEC 62717:2014 received the second Amendment in January of the year 2019. In Pakistan, in addition to making changes considered relevant to the country, they use the text in the English language (without translating it into a local language version) and follow the IEC. Among the lessons learned during the activities within the technical standardization sector, one concerns the ease that an established normative document brings to the process. Document IEC 62471, 2006 already has a defined and numbered version for the Brazilian standard project (ABNT-CB-003 PROJECT 003:034.001-151 - Photobiological safety of lamps and lamp system, dated September 2020, but not yet defined as a priority. Another need noted is the absence of a procedure for calibrating a photometer. The IEC document indicates the lamp base as the location for determining the lamp temperature and "hopes it will not emit significant infrared radiation". In an experiment using a procedure with thermal image equipment, brand Flir, the maximum temperature was found to occur on the lamp body and not at the base. The lamp base is the common situation for the incandescent and HID lamps types, not for the WLEDi lamp. Figure 7 shows the maximum external temperature on the body of 35 WLEDi lamps, E-27 (the average value; for the environment under 26 °C), without significant previous use (~ 0 h), when energized at two nominal voltages of Brazilian networks (127V and 220V) and tree different position each lamp (including base up, down and at the horizontal plane).

Figure 7. Maximum external temperature at the body of 35 new WLEDi lamps (not used ~ 0 h).



The luminous efficiency of lamps purchased from the Brazilian market (result)

The mean, standard error, and range of values (maximum-minimum) of the sample with 35 lamps (base up) and 14 different brands were calculated, both when energized at 127 V and 220 V. Those statistics data from the sample are presented in Table 1.

Table 1. Statistics values for 35 lamps under 127 V and 220 V, 60 Hz.

Lamp WLEDi, E-27 (statistics)	**Luminous Efficiency (*) 127 V (lm/W)**	**Luminous Efficiency (*) 220 V (lm/W)**
average	105 ± 2	109 ± 2
maximum	138.1	139.3
minimum	82.7	84.4
Delta (max-min)	55.4	54.9

Note: (*) For the calculation of the average (± standard error) 35 results were considered under 127 V and 220 V.

The analysis of the values set in Table 1 concerning results collected from the literature [20] also for values of 127 V and 220 V, the authors used five different types of lamps, for three groups (C, D, and E [20]) there is an agreement between the results, the luminous efficiency presented a higher value for the 220 V condition. The article used above dates from the year 2015 [20], which allows us to infer that there was an increase, albeit modest, in the average luminous efficiency of this product class. The last two lamps included in the sample (for the next long-term experiment of the research) are based on type G-13 (WLEDi tube, length 60 cm) and have a nominal luminous efficiency of 100 lm/W.

THDi and Power Factor (PF; result)

The use of light sources with lower electricity consumption for an equal amount of light emitted increased the penetration of fluorescent technology. The impact of the presence of sources with greater luminous efficiency became the subject of research, which had the incandescent source as a guiding reference [21]. The abnormal voltage conditions of the electrical network also motivated different behaviors according to the type of circuit used to ballast the electrical current necessary for the technology of conventional tubular fluorescent lamps [22]. In the year 2005, the focus on the production of distortions (THD) and PF had shifted to CFL, also due to market penetration [23]. When evaluating the performance differences between a type of fluorescent technology (CFL) and LED, when under different power grid conditions, the Hispanic-Swedish group of researchers stated that the harmonic component emission depends on the driver circuit topology and THDv level of the real network, which differs from the low THDv conditions usually present in laboratory measurements [24]. Tables 2 to 4 present measurement results of active electrical power, total harmonic distortion (THDi) for the electrical current, total power factor (PF) of LED, E-27, lamps under 127 V, 60 Hz, calculations performed based on results from three different equipment, which include estimation for the displacement factor (PF_1, or the fundamental power factor component) [5].

Table 2. Active electrical power measured for lamps under 127 V, 60 Hz, and three different instruments, brand (YEW, XITRON, ELSPEC), values in W.

Lamp Identification: (number) code	**YEW (*) (W)**	**XITRON (**) (W)**	**ELSPEC (***) (W)**
(**#** 4) G3.1	8.475	--	8.32
(**#** 1) G3.5	8.671	--	8.50
(**#** 7) L1.1	7.700	--	7.61
(**#** 6) L1.2	7.454	--	7.32
(**#** 4) L2.1	9.037	--	8.90
incandescent	--	--	59.1 - 59.2
CFL	--	--	14.3 - 15.9
LED tubular (# 8)	--	--	8.9 - 9.0
LED tubular (# 9)	--	--	9.1 - 9.3

<u>Notes:</u> (*) YOKOGAWA (YEW) brand instrument, model WT3000, used until Mar.2021; (**) Values not available; (***) Measurements performed in a second lab. of the IEE-USP, in Nov., 2021, the ranges presented were estimated from the test sheets data; The ELSPEC incertitude estimation is 2.9 %.

The measurement of initial electric lamp characteristics, at the IEE-USP power quality lab., showed error for PF values previously obtained with the YEW brand equipment, WT3000 (all five specimens: # 4, # 1, # 7, # 6 and # 3 showed PF 0.99).

Still on the result of the PF with equipment brand ELSPEC, model G4500, XITRON and five WLEDi lamps, 9 W, E-27, PF > 0.70, comparatively, the XITRON equipment presented the lower value regardless of the type of WLEDi lamp considered.

Table 3. Total power factor (PF) for lamps, dimensionless values, and the total current harmonic distortion (THDi) for the electric current of lamps under 127 V, 60 Hz from three different devices, values in %.

Lamp identification (number/code)	**YEW (*) PF**	**XITRON PF**	**ELSPEC PF(**)**	**YEW (*) THDi (%)**	**XITRON THDi (%)**	**ELSPEC THDi (**) (%)**
(**#** 4) G3.1	0.956	0.952	-0.956	28.7	28.9	27.8
(**#** 1) G3.5	0.958	0.949	-0.957	25.9_5	26.6	24.9
(**#** 7) L1.1	0.935	0.930	-0.935	36.2	35.9	35.2
(**#** 6) L1.2	0.935	0.924	-0.934	34.9	34.6	33.6
(**#** 4) L2.1	0.975	0.968	-0.972	17.9	18.2	16.77
incandescent	--	--	-0.999_5 to -1.000	--	--	0.234 to 0.332
CFL	--	--	-0.594 to -0.607	--	--	100.0
LED tubular (# 8)	--	--	-0.978 to -0.984	--	--	14.81 to 16.52
LED tubular (# 9)	--	--	-0.986 to -0.988	--	--	7.61 to 9.45

<u>Notes:</u> (*) YOKOGAWA (YEW) brand, model WT3000, used until Mar., 2021, the PF values shown are the result of a calculation performed (the data presented for the equipment were changed after the fourth acquisition of the 35 lamp set), for further information, see text above, at the beginning of this part of the article, "THD, Power Factor (PF; result)";
(**) Measurements were performed at a second lab. of the IEE-USP, in Nov., 2021, the values that have a negative signal can be viewed as capacitive load. The ranges presented were estimated from test sheets data, and the nominal incertitude is ± 0.2 % (true power factor) and ± 0.25 % (THDi).

Table 4. Average for values of three different types of equipment of the total power factor (PF), total harmonic distortion (THDi), electric current, and PF_1 of the fundamental component of lamps under 127 V, 60 Hz.

Lamp identification (number/code)	**PF (*) (%)**	**THDi (%)**	**ELSPEC Electric current (**) fundamental component (A)**	**PF_1 (***) (%)**
(**#** 4) G3.1	95.4 ± 0.1	28.4 ± 0.3	0.066	99.2
(**#** 1) G3.1	95.5 ± 0.3	25.8 ± 0.5	0.068_5	98.6
(**#** 7) G3.1s	93.3 ± 0.2	35.8 ± 0.3	0.060	99.1
(**#** 6) G3.1	93.1 ± 0.4	34.4 ± 0.4	0.059	98.4_5
(**#** 4) G3.1	97.1 ± 0.2	17.6 ± 0.4	*0.070_5*	98.6
incandescent	--	--	*0.47*	--
CFL	--	--	*0.132_5*	--
LED tubular (# 8)	--	--	0.071	--
LED tubular (# 8)	--	--	0.073	--

Notes: (*) For the calculation of the mean (± standard error) each value calculated for the YOKOGAWA equipment and converted into % was considered, and for the calculation of the standard error in the mean, n= 3 was used;

(**) Estimated result of test sheets carried out in Nov., 2021 that graphically present the relevant harmonic components; and

(***) Estimated result based on approximate calculation, as per ref. IEEE Standard 1459-2010, item 3.1.2.16 Power factor, p.12-13 [25].

The ELSPEC equipment, in the sampling of the five WLEDi lamps, 9 W, always presented the lowest THDi value among the three types of equipment used (XITRON and YOKOGAWA). Those five lamps that had been measured in another laboratory (with equipment brand: XITRON and YOKOGAWA) within the sample of 35 lamps (sampled in Nov., 2021), it was measured again together with two tubular WLEDi, 9 W, base G-13, 60 cm; one incandescent lamp and one CFL intended to be used as a reference in possible repetitions of the experiment conducted in the IEE power quality lab.

Light bulbs, electricity in the Brazilian residential sector

Having the capacity to estimate the number of light bulbs installed in a Brazilian home sector is important for the planning end-use of energy, estimating the sectorial consumption of electricity. MARCOS PEREIRA ESTELLITA LINS, et al. 2002 [26] presented an estimate for the year 2002 in this regard, based on a survey carried out for the National Electric Energy Conservation Program - PROCEL by Brazilian electric energy concessionaires (still state-owned). The consumption estimate is presented in Table 5 and it was based on the nominal electrical power (60 W) of the incandescent lamp.

Table 5. Modeling results for the residential sector from PROCEL survey (year 2002) data [26].

Country region and	**Lamps Number (amount)**	**Lamps/ Residence**	**Consumption monthly (kWh/month)**
BR	76,315	8.115	4.008
North	32,186	7.046	5.116
South	44,136	9.125	2.664

VILLAREAL, M.J.C. et al. 2016 [27] described the consumption of electricity in Brazilian households between 1985 and 2013, using linear regression and as "explanatory variables" they used the number of households, the actual consumption of families as a source of family income and the electricity tariff for the households. Thus, they were able to account for the reduction in household electricity consumption caused by the energy crisis in 2001. They safely suggested the existence of a long-term relationship between household electricity consumption and the explanatory variables. For the year 2012 and Brazilian consumption of electricity for light bulbs in the residential sector, they presented the 15 % fraction (or about 17 TWh), after electric showers (first) and refrigerators (second). Another study made by ABRAHÃO, KC de FJ; SOUZA, RVG de., 2021 [28] analyzed the residential consumption of electricity in Brazil, between 2000 and 2018, and presented as main results: "(i) the growth of the number of households was recognized as one of the main drivers of consumption growth; (ii) household income showed no control over consumption in hot climate regions, except in low-income households; (iii) the tariff showed to impose restrictions on consumption, mainly in low-income households. In an unprecedented way, the results showed that residential electricity consumption in Brazil varies with the age of the population, with a tendency for consumption to grow up to 59 years of age, and a sharp reduction from this onwards 60 years old".

Discussion

For the year 2012, the Brazilian consumption of electricity in the residential sector, for light bulbs, received an estimation of 15 % of the total, around 17 TWh [27]. Data collected (twenty years ago) showed estimation of 8.1 lamp/house, monthly electricity consumption of 4.0 kWh/month, and considered as the most frequently occurring lighting load bulbs (Brazil, 2002), 60 W incandescent [26]. The second published data (Brazil, 2019) indicates an average, reduced, value of 6.50 lamp/house [2].

This article considered aspects related to lighting in the Brazilian residential sector and the SSL light bulb technology (Inorganic White Lighting Emitting Diode - WLEDi) marketed in developing countries, such as the initial electrical, photometric characteristics, radiometric characteristics (7 kh), light depreciation, median sample useful life, includes aspects to broaden the discussion on the final use of electrical energy, light output efficiency, power factor, THDi, technical standard, labeling, the implications of plastic waste at the end of the product's useful life, the part of the lamp considered was the light diffuser and prices (scrap dealer) to value discarded metals, a topic that sought to lay the foundation for future investigation of possible actions whose benefits will not be energetic. Lamp failure and light output depreciation data were collected during a long-term experiment with WLEDi lamps purchased in the Brazilian market.

The result of the long-term experiment showed agreement with the users' position; the brands used in the sample are not global (from the four traditional lamp manufacturers). The occurrence of reports from local consumers about the product's very short useful life has been verified. This agrees with a statement by NARENDRAN, N., 2017 [29] made based on a study focused on the reliability of the LED system, he revealed that: "some LED products available in the US consumer market and certain applications, they can fail much earlier than the manufacturers' specifications suggest to consumers." And that "industry test standards will evolve to ensure more accurate LED system life estimates" [29]. Data that could support a useful life of 25 kh (L_{70}, at the packaging of all lamps) have not yet been collected locally. Luminous depreciation was quantified and is presented together with other results. Luminous depreciation has distinct behavior groups; it is not similar, even for a single brand. The catastrophic failures (when considering SSL technology) occurred in the inverse order of the nominal electrical power, first to 12 W, then 9 W. Lamps that did not show abrupt failure after 7 kh of the experiment are 8 W and 7 W. Only brand # 5 (coding used for results dissemination purposes), nominal 8 W did not show L_{70} fault until 7 kh of the first long-term experiment conducted.

There is still no closed definition concerning the lamp seasoning period, that is, which time should be considered as an "initial" or "zero hour" condition. For 5 mm LED type, there is information in the literature about: The lifetime" of the LED device (5 mm encapsulation) for the signaling sector has been set at 50 % of the light output not from the initial one, but for the light output of LED devices it was verified to occur at 192 hours after the initial energization (industry's standard definition for lifetime [30]). Currently, the "useful life" information contained in the packaging of lighting products has a different useful life time definition[275], which can be interpreted by the consumer as elapsed 25 thousand hours of the product use it should still be able to provide light depreciated by up to 30 % concerning the "initial light output". Therefore, for LED (5 mm) the suggested minimum seasoning period used to be 192 h.

The current IEC 62717 document [18] has three references to the term aging time: a) recommends (can be chosen) 500 h for electrical characteristics; b) p.13, Table 1, item k, Mandatory appointment if the seasonal period is different from zero hours; and c) p.27, Method of LED measuring module characteristics, "Unless otherwise declared, LED modules do not require any aging before testing. An aging period of up to 1000 h may be specified by the manufacturer [18]. As shown in this article (see Figure 2 and related text) the light output behavior at the first 815 h varies according to the type of WLEDi lamp; - p.25 [18], unless otherwise specified, all measurements shall be made in a draft-free room at a relative humidity of 65 % maximum."

[275] (L_{70}) or useful lamp life that is equivalent to the time the LED light source takes until its light output (luminous flux) reaches 70 % concerning the initial luminous flux.

Therefore, there is a limit for the maximum relative humidity, suggesting that the high relative humidity influences the measurement to determine the characteristics of the so-called "LED module".

It does not have scale, capable of identifying differences between products and facilitating understanding for the consumer, in addition to the luminous efficiency value. The suggestion of this article is to incorporate other parameters, within a scale to be built that can increase the useful information to the consumer when making a purchase decision, in addition to the price of the product. When doing a local search on the status of the number of records of the WLEDi lamp product in the Brazilian market with a label, records could be accessed from an internet tool that can be used (the electronic address to assess it is: http://registro.inmetro.gov.br/consulta/). The label (PBE) contained in the WLEDi lamps sold in the Brazilian market differs from the European model.

The measurement of initial characteristics, in the power quality laboratory of the IEE-USP, of the electrical parameters revealed the occurrence of an error in the previous sampling, for PF values with the equipment brand YOKOGAWA - YEW, WT3000 (all five specimens: # 4, # 1, # 7, # 6 and # 3 had presented PF 0.99). The change occurred during the sampling of 35 lamps, the first readings of the PF with the YEW equipment, the three reference lamps, and the first lamps were correct only. The verification was carried out from active and apparent power, however, an unexpected change occurred and resulted in non-conforming values.

Based on the records obtained with the equipment ELSPEC brand, model G4500, five WLEDi lamps, 9 W (nominal power), and considering a suggestion from the literature [25] for approximation on calculation procedure, the fundamental component displacement factor (PF_1) for the five lamps was estimated (see Table 4). Although approximate, the calculation result enables analysis concerning an older technology, the CFL displacement factor (p.225, Table 13 - Power factor and displacement factor values) from the literature [31]. The authors presented a scenario regarding the replacement of 90 % of incandescent lamps by CFL, which led to a degradation of the parameter PF and (PF_1), both from 0.95 to 0.84 (PF) and 0.86 (PF_1) from measurements carried out at the output of the distribution transformer. In the case of the WLEDi lamp from the Brazilian market {(# 4) G3.1}, PF, an average (from three instruments reading) of (95.4 ± 0.1) % was defined, and for (PF_1) a calculated value of 99.2%, both higher regarding load configuration with the CFL analyzed from the literature [31]. The access and evaluation of values of luminous efficiency between light sources have been a widespread practice used to point out the technology limit of a certain family of type A WLEDi lamps (base E-27) concerning results obtained from experimental practices. The data for luminous efficiency that was obtained from the IEE-USP laboratory by sampling 35 lamps specimens provided were processed and the representative statistics were fixed and presented in Table 1. The average value was analyzed concerning data from specimens evaluated in Brazil, also at two energizing voltages representative of the electrical systems [20], having revealed evolution on a time basis. There was an increase, albeit timid, in the average luminous efficiency between the sample's average values, in an absolute of 4 lm/W (3.8%).

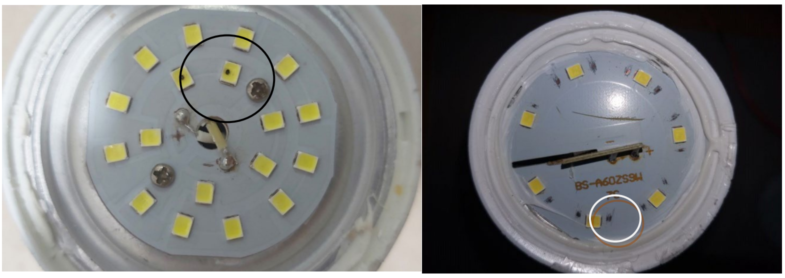
Improvement can also be observed concerning the values presented in Table 3 and data from the literature for the year 2015 [20], the same specimens, and considering the THDi parameter. In the current sample, although reduced, the presence of a specimen with high THDi (> 86 %) was not observed.

There are seven lamps from the sample (35 lamps) with a maximum temperature above 90 °C and one above 100 °C (see Figure 7 – Maximum external temperature at the body of WLEDi lamps) Do they have a Brazilian safety compliance label (the answer is yes, they do).

To increase the robustness of the analysis of the luminous efficiency values determined in this article, they were compared to the data set out in the literature [32]. A reference value is a reference to the Chinese standard (GB 30255-2019 - Minimum allowable values of energy efficiency and energy efficiency grade of LED products for indoor lighting) at a point of the order of ≥ 62 lm/W regardless of the light output values between zero and 2.5 klm; the European standard (the year 2019) whose reference line limit increases with a logarithmic and continuous profile, concerning the increase in light output (at x-axis) and it crosses the threshold of 100 lm/W (horizontal line parallel to the x-axis) close to 1.5 klm [32] The records of specimens indicate a maximum of 160 lm/W (close to 0.55 klm) and the highest frequency of records is between (80 and 120) lm/W. For the light output corresponding to the incandescent pattern, 60 W registers are in the range from the Chinese standard limit to close to 135 lm/W. Furthermore, the part of item 4.4 "Lumen maintenance", from the Chinese standard (GB 30255-2019) states that for LED lamps at 3000 h the light output must not be less than the required nominal lumen maintenance associated with the expected rated life at that period. According to the stated nominal life, the required lumen maintenance value must be classified according to a formula that could not be accessed in the literature yet.

After more than 20 years that NARENDRAN, N., et al. 2001 [33] posed initially a relevant question for discussion by the scientific community: “What is useful life for white light LEDs?”, accompanied by the argument that "the LED device, normally, does not present catastrophic failure, it presents continued depreciation", the results presented in this article demonstrate that catastrophic failures exist, and its manifestation can be visible to the naked eye, as shown by the marks on the top of the devices shown in Figure 8 for the closing of this article.

Figure 8. WLEDi lamp (E-27), 9 W, type with ID #1, after 3255 h (catastrophic failure, at right); another module with two defective devices on the left (see device inside the circle).



Acknowledgment: To FATEC-SP for the opportunity to collaborate with the training of the student Hélio Akira Furuya, who helped during the samplings in the long-term experiment with a sample of WLEDi lamps, E-27 (period from Dec., 2018 to Nov., 2019); to the IAG-USP, Teacher Márcia Akemi Yamasoe for using the spectrometer (Luzchem brand, model SPR-03, HR4C2217 series); to the Materials Department at USP, Macromolecules Lab., Teacher Wang Shu Hui for the infrastructure and the spectrophotometer and the IEE-USP for data obtained at labs. from WLEDi lamps.

References

[1] EMPRESA DE PESQUISA ENERGÉTICA. Consumo Mensal de Energia Elétrica por Classe (regiões e subsistemas). 2022. Available in: https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/consumo-de-energia-eletrica. Accessed: April 8, 2022.

[2] ELETROBRAS. Pesquisa de Posse e Hábitos de Uso de Equipamentos Elétricos na Classe Residencial. 2019. 357p. Available in: https://eletrobras.com/pt/AreasdeAtuacao/BRASIL.pdf. Accessed: April 8, 2022.

[3] MODEL REGULATION GUIDELINES FOR GENERAL LIGHTING, ENERGY EFFICIENCY AND FUNCTIONAL PERFORMANCE REQUIREMENTS FOR GENERAL SERVICE LAMPS. 17p. Feb. 2021. Available in: https://cleanlightingcoalition.org/wp-content/uploads/sites/96/UNEP_U4E_Model-Regulation_GSL_Final_Feb2021.pdf.

[4] MELERO, J.C.M., BURINI JUNIOR, E.C., SAUER, I.L. Lámpara WLEDi com base tipo E-27: Desempeño energético y calidad de la energia eléctrica. XLVII Simposium Nacional de Alumbrado. Vigo, España. 2021. Abstract available in: https://www.ceisp.com/simposiums/vigo-2021/abstracts/lampara-wledi-con-base-tipo-e-27-desempeno-energetico-y-calidad-de-la-energia-electrica/. Accessed: April 30, 2022.

[5] IEC 62612 (Edition 1.2 2018-08, CONSOLIDATED VERSION). Self-ballasted LED lamps for general lighting services with supply voltages > 50 V – Performance requirements. Annex C (normative) Measurement of displacement factor; Annex D (informative) Explanation of displacement factor.

[6] DRÁPELA, J., et al. 2007. Interharmonic - Flicker Curves of Lamps and Compatibility Lever for Interharmonics Voltages. IEEE Explore, p.1552-1557.

[7] CAI, R.; Cobben, J.F.G.; Myrzik, J.M.A.; Blom, J.H.; Kling, W.L. (2009). Flicker responses of different lamp types. 3(9), 816–0. doi:10.1049/iet-gtd.2008.0429.

[8] GIL-DE-CASTRO, A. et al. Light intensity variation (Flicker) and harmonic emission related to LED lamps. Electric Power Systems Research, v.147, p.107-114, 2017.

[9] BURINI, E. C. et al. Light Output Measurement of Solid State Lighting Technology, 2019 4th International Symposium on Instrumentation Systems, Circuits and Transducers (INSCIT), 2019, pp. 1-6, doi: 10.1109/INSCIT.2019.8868680.

[10] IES LM-54-1984 (1989) IES Guide to Lamp Seasoning, Journal of the Illuminating Engineering Society, 18:2, 150-152, DOI: 10.1080/00994480.1989.10748775.

[11] KE, H.-L., et al. (2018). Lumen degradation analysis of LED lamps based on the subsystem isolation method. Applied Optics, 57(4), p.849-854.

[12] Annex of the INMETRO Ordenance n. 144/2015 - REQUISITOS DE AVALIAÇÃO DA CONFORMIDADE PARA LÂMPADAS LED COM DISPOSITIVO INTEGRADO À BASE. 18p.

[13] Brazilian Certification Label for LED Lamps. Available in: https://www.brics-ocp.com.br/lampadas-led-e-a-certificacao-inmetro/.

[14] Example of the Brazilian label for public road lighting luminaire. Available in: https://www.ledstar.com.br/regulamentacao-inmetro-luminaria-publica/.

[15] ECOFYS Impacts of the EU's Ecodesign and Energy/Tyre Labelling Legislation on Third Jurisdictions (Project number: DESNL13605). 93p.

[16] YURTSEVEN, M. B., Sermin Onaygil. 2015. Latest Developments in LED Standards. LIGHT SVĚTLO 2015, p.37-40. DOI:10.13164/conf.light.2015.37.

[17] ABNT/CB-003 PROJETO 003:034.001-150 (IEC 62717). DEZ 2021. LED modules for general lighting - Performance requirements. 50p.

[18] IEC 62717:2014/AMD2:2019 Amendment 2 - LED modules for general lighting - Performance requirements. 44p.

[19] PS: 5253. 2017 (IEC 62717:2011). PAKISTAN STANDARD, LED MODULES FOR GENERAL LIGHTING-PERFORMANCE REQUIREMENTS, 44p.

[20] FORTES, M. Z. et al. 2015. Qualidade de Energia em Lâmpadas LED – Comparação em suas Tensões Usuais 127 e 220V. Conference: XI Conferência Brasileira sobre Qualidade da Energia Elétrica At: Campina Grande - PB, v.1, July 2015. DOI: 10.13140/RG.2.1.3607.7284.

[21] ETEZADI-AMOLI, M.; FLORENCE. (1989). Power factor and harmonic distortion characteristics of energy efficient lamps, IEEE Transactions on Power Delivery, v.4, n.3, p.1965-1969.

[22] CHEN, M. T., FU, C. M. (1997). Characteristics of fluorescent lamps under abnormal system voltage conditions. Electric power systems research, v.41, n.2, p.99-107.

[23] RADAKOVIC, Z. et al. (2005). The voltage distortion in low-voltage networks caused by compact fluorescent lamps with electronic gear. v.73, n.2, p.129–136.

[24] GIL-DE-CASTRO, A. et al. Differences in the performance between CFL and LED lamps under different voltage distortions," 2018 18th International Conference on Harmonics and Quality of Power (ICHQP), 2018, p.1-6.

[25] IEEE Standard Definitions for the Measurement of Electric Power Quantities Under Sinusoidal, Non-Sinusoidal, Balanced, or Unbalanced Conditions, IEEE Standard 1459-2010, 3.1.2.16 Power factor, p.12-13, 2010.

[26] LINS, M. P. E. et al. (2002). Regional Variations in Energy Consumption of Appliances: Conditional Demand Analysis Applied to Brazilian Households. 117 (1-4), p.235–246.

[27] VILLAREAL, Maria José Charfuelan; Moreira, João Manoel Losada (2016). Household consumption of electricity in Brazil between 1985 and 2013. Energy Policy, v.96(C), p.251–259.

[28] ABRAHÃO, K. C. de F. J.; SOUZA, R. V. G. de. What has driven the growth of Brazil´s residential electricity consumption during the last 19 years? An index decomposition analysis. Ambiente Construído, Porto Alegre, v.21, n.2, p.7-39, abr./jun. 2021.

[29] NARENDRAN, N. (2017). Industry test standards must evolve to ensure accurate LED system life estimates. LEDs Magazine, p.23–24, May/June 2017.

[30] CHIAO, CHIH-HUA; HAMADA, MICHAEL (1996). ROBUST RELIABILITY FOR LIGHT EMITTING DIODES USING DEGRADATION MEASUREMENTS. Quality and Reliability Engineering International, 12(2), 89–94. doi:10.1002/(SICI)1099-1638(199603)12:2<89::AID-QRE997>3.0.CO;2-D.

[31] CHATZAKIS, I. et al. 2007. The Influence of Replacement of Incandescent Lamps with Compact Fluorescents to the Harmonic Distortion in Non-Interconnected Island Grids. 7th WSEAS International Conference on Electric Power Systems, High Voltages, Electric Machines, Venice, Italy, November 21-23, p.219-226.

[32] LIANG, Xiuying, Li, Jiayang, Michael Scholand. New Trends of Energy Efficiency Requirements for LED Lighting Products in China, EU and US. CLASP. EEDAL19', Ji'Nan, China. (eedal_jiayang_paper_37). Available in: <eedal_jiayang_paper_37%20(1).pdf>.

[33] NARENDRAN, N., J. Bullough, N. Maliyagoda, and A. Bierman, "What is useful life for white light LEDs ?," J. Illum. Eng. Soc., v.30, n.1, p.57–67, Winter 2001.

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