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# Energy and Environmental Impact of Light Pollution from Outdoor Advertising: Energy Waste

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Light pollution, primarily derived from the excessive use of illuminated panels in outdoor advertising, has a significant economic and environmental impact. In economic terms, unnecessary energy consumption increases companies' operating costs and contributes to resource waste. In environmental terms, this pollution alters ecosystems, affects biodiversity, and generates a larger carbon footprint, accelerating climate change. Furthermore, excessive artificial light affects human health, disrupting natural sleep cycles. Combating this phenomenon involves reducing energy consumption and promoting more sustainable advertising solutions. This study seeks to quantify the energy waste of advertising panels on a specific street, analysing only daylight lighting schedules. There is no exact data on the number of illuminated panels on Alfredo Mendiola Avenue, one of the largest public thoroughfares in Lima. It is estimated that there are approximately 1,015 outdoor advertising elements of various types and sizes (signs or panels), of which 11 illuminated panels existed at the time of the research in the study area. The results indicate that each panel, with the most common characteristics, consumes between 8.62 kWh and 72.23 kWh of energy, which generates a significant impact on the environment through $CO_2$ generation and wasted energy expenditure. The results obtained will generate relevant information to promote more efficient energy use in outdoor advertising and avoid energy waste, contributing to environmental sustainability and cost reduction.

## 1. Introduction

External advertising on roads or buildings using light panels with LCD (Liquid Crystal Display) screens or liquid crystal displays or LED (Light Emitting Diode) has been overused in many places in recent times, generating this artificial lighting impacts that negatively affect ecosystems (Lazzeroni, Guerrero and García, 2020). LED advertising was implemented alongside the use of street lighting, and its exponential use is based primarily on its long theoretical lifespan, estimated at approximately 60,000 hours with 70 % initial flux. In addition to reduced maintenance costs, the lack of infrared or ultraviolet radiation emissions, improved design control, and low-voltage operation, it also has some disadvantages, such as potential health risks from intrusive blue light and environmental impact due to the intense light emitted at wavelengths close to 440 nm (Derremochea et al., 2011).Light panels are most commonly used in commercial marketing to promote the products and services of companies and institutions, due to their attractive design and versatility, seeking to impact potential customers or consumers. Light panels are a type of outdoor advertising element that emits light to illuminate or display visual information. Their effectiveness is based on consumers thanks to their brightness and visual appeal, due to the use of LED cells. These panels have acquired advantages of certain energy efficiency with soft, uniform, shadow-free light, versatile design and long life (Clear Channel Perú, 2023).
The aforementioned type of advertising causes negative environmental impacts in many cities, for example, in Cuenca, Ecuador, it was found that excessive light causes discomfort to the human eye and other inconveniences (Gómez and Guaman, 2023). Other consequences are urban pollution due to prolonged night-time activities with the presence of illuminated panels to promote services and goods, which cause harm to the

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quality of life and natural quality of the sky, as is the case in Mexico (Hernández-Torres, et al., 2024). In the effort to measure light pollution, resources such as remote sensing have been used to facilitate evaluation and modelling (Durán, 2024).Light pollution resulting from the excessive and unnecessary use of lighting can affect legal assets, as well as rights that must be protected; however, these measures still lack an adequate response in Peruvian legislation. In this regard, there is a need to implement control measures and technological innovation in the use of lighting elements, pursuing efficient marketing and also seeking energy savings and efficiency, accompanied by regulatory treatment that aids in preventive proposals, control, and the fight against environmental pollution (Rios, 2008). In countries like Spain, light pollution has been addressed with great emphasis. There are regulations and recommendation guides that help manage the problem of artificial pollution. For example, the Galician Cultural Council recommends: a verifiable reduction in light pollution as a basic criterion in the design of new buildings and the modification of existing ones; an environmental impact assessment is recommended for lighting projects; avoiding ornamental lighting and decorations, dimming lighting, and reducing the intensity of artificial light emitted at night, among others (Baras et al., 2025).
LED advertising has evolved to become more eye-catching and attractive due to its brightness, which has impacted customers of products and services. Its excessive use also generates waste or excessive energy consumption at times when the panels dim or lose their focus in the bright daylight, as they lack the same brightness and attention as at night. However, it consumes excessive amounts of energy, so its use should be avoided or alternative and sustainable energy sources should be sought, such as wind power (Tijero, 2020) or photovoltaic energy with solar panel power (Ramirez, 2012). The objective of the research was to determine the energy consumed by the light panels located on Alfredo Mendiola Avenue between blocks 10 to 60, during daylight hours between 6:30 a.m. and 6:00 p.m., which will be called "wasted energy", a period of time when the light panels do not comply with 100 %, with the aim of capturing the attention of customers or people looking for information on products and services, by going unnoticed in daylight, the cost probably being greater than the benefit.

## 2. Methodology

For the development of the research the following procedure was followed:

### 2.1 Geographic location of the panels

Alfredo Mendiola Avenue is a busy road in Lima. It connects the districts of San Martín de Porres, Independencia, Los Olivos, and Comas from south to north. It begins at Zarumilla Avenue. A large number of outdoor advertising elements (EPE) are installed on this avenue, considering the large amount of vehicular traffic and the large number of people who visit shopping centers such as Plaza Norte and Plaza Center San Martin de Porres, Mega plaza, Metro Supermarkets and Plaza Vea, educational canter's such as SENATI, Continental University, César Vallejo University, Private University of the North, Technological University of Peru, Scientific University, and other smaller shopping canters. This high-traffic nature of this road is conducive to outdoor advertising, using illuminated and illuminated panels offering different products and services.
"Light panels" were those that have an illuminated surface using LED or fluorescent technology to emit light. They can be rectangular, square, or other shapes, providing highly versatile lighting in different contexts such as decoration, signage, and advertising. For the purpose of the investigation, light panels that were lit during the day and installed on Alfredo Mendiola Avenue in the section between the intersection with Tomás Valle Avenue and Naranjal Avenue (see Table 1) were identified, similar to those shown in Figures 1a and 1b.

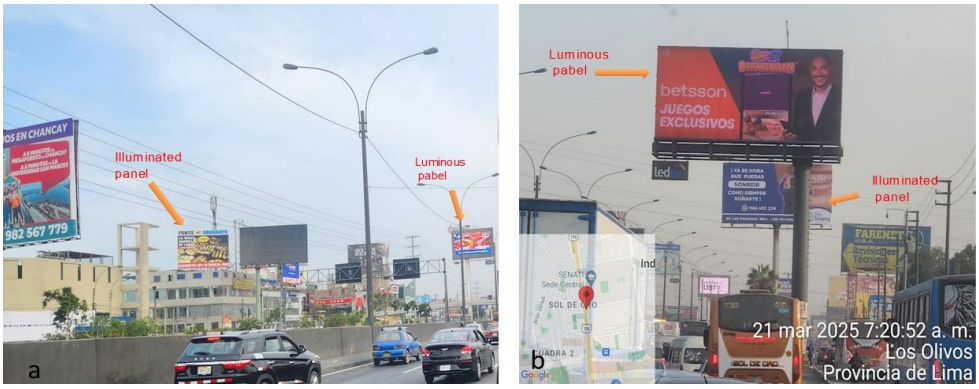


*Figure 1a y 1b: Luminous panels on and illuminated panels off during daylight hours*

*Table 1: Location and size of the light panels*

| Panel code | Location | Coordinates | Face number | Dimensions (m x m) | Area ($m^2$) |
|---|---|---|---|---|---|
| P01 | Alfredo Mendiola 1400 Av. (Plaza Norte) | 120072S, 770602W | 1 | 3 x 24 | 72 |
| P02 | Alfredo Mendiola Av.,1400 | 120065S, 770610W | 1 | 3.5 x 8 | 28 |
| P03 | Ref.: Apolo XI 168 street, | 120046S, 770616W | 1 | 4 x 9 | 36 |
| P04 | Alfredo Mendiola Av. 6258 4031 | 120010S, 770621W | 2 | 4 x 8 | 32 |
| P05 | AV. Alfredo Mendiola, Altura Av. Globo Terráqueo 14 (SENATI) | 119996S, 770624W | 1 | 4 x 9 | 36 |
| P06 | Alfredo Mendiola Av. 3968 | 119942S, 770627W | 1 | 3 x 12 | 36 |
| P07 | Alfredo Mendiola Av 25017 | 119919S, 770636W | 1 | 4 x 9 | 36 |
| P08 | Alfredo Mendiola Av. 5184 | 119747S, 770658W | 1 | 3 x 7 | 21 |
| P09 | Urb. Panamericana Norte | 119948S, 770639W | 1 | 4.5 x 7 | 31.5 |
| P10 | Alfredo Mendiola Av. 3475 | 119946S, 770638W | 1 | 4 x 9 | 36 |
| P11 | Globo Terráqueo street 7201 | 120023S, 770625W | 2 | 4.5 x 9 | 40.5 |

Fuente: Casimiro (2024)

### 2.2 Monitoring the operation of the luminous panels

Monitoring was conducted to verify the time the panels were on over a 15-day period. Their location was also determined, and a luxmeter was used to measure the illuminance of the panels at a distance of 21.21 meters, at a 45-degree angle to the ground. Measurements were taken at night; they were not taken during the day to avoid dimming due to sunlight, which caused the panels' illumination to be barely perceptible (as seen in Figures 1a and 1b).

### 2.3 Method for calculating the energy consumed by the panels

The procedure was carried out taking into account the scientific literature (Secue et al. 2018), as follows:

- The luminous flux (Φ) in lumens was calculated from the luminous intensity (illuminance) measured in the monitoring, using the equation Eq(1).

$$\Phi = I * \omega \qquad (1)$$

Where:
I: Luminous intensity (cd), as the measurements are in lux, it is converted to candelas using the equation Eq(2)

$$\mathrm{E} = \mathrm{I} * d^2 \qquad (2)$$

ω: Solid angle of emission (sr)

For a light panel that emits light uniformly in a half-space (180°), a solid angle of approximately 6.28 sr.

- Calculation of electrical efficiency (P)

Power (P) is calculated from the luminous efficiency (η) in lumens/watt. That is, the number of lumens produced per watt consumed is determined using the equation Eq(3).

$$P = \frac{\Phi}{\eta} \qquad (3)$$

Considering the typical value of luminous efficiency: For LED: η = 80-150 lm/W, an average of 150 lm/W was used for the research

- Calculation of daily consumption: Using equation Eq(4), the energy consumption of a panel was found

$$E_{diartio} = P * t \qquad (4)$$

Where t: is the panel operating time in hours in kW

When you have specific data on LED panels, the calculation can be made from the pixels used in the construction of the panel, the modules used and other details (as indicated by a company in the sector), mentioning that the power according to the module is generally: 2.9 mm modules 162.5 Watts/module, 3.9 mm modules: 400 watts/module, 4.6 mm module: 180 watts/module, 8 mm module: 200 watts/module and 6.9 mm module: 400 watts/module (Camacho 2024).

## 3. Results and discussion

In order to establish the energy consumption of the light panels of the sample of panels located on Alfredo Mendiola Avenue, the following was found:

### 3.1 Operating time of the light panels

After monitoring for 15 days, it was found that, of the 11 light panels indicated in Table 1, panel P01 was on from 6:00 p.m. to midnight. Furthermore, with the exception of one or two days (probably for contractual reasons), the other panels were on 24 hours a day. Table 2 shows the hours during which the light panels remained on (the objective of this investigation; night-time hours are not included).

*Table 2: Average daily energy consumption (daytime only) of the light panel*

| Panel | E: Illumi-nance (lux) | d: Distance (m) | I: Light intensity (cd) | ω: Solid angle of emission (sr) | Φ: Luminous flux (lm) | η: Luminous efficiency (lm/W) | P: Electrical power (W) | t: Daily usage time (h) | $E_{diary}$: Energy consumption (kWh) |
|---|---|---|---|---|---|---|---|---|---|
| P01 | 470 | 21.21 | 211436.13 | 6.28 | 1327818.88 | 150 | 8852.13 | 06 | 53.11 |
| P02 | 51.54 | 21.21 | 23186.00 | 6.28 | 145608.05 | 150 | 970.72 | 12 | 11.65 |
| P03 | 38.16 | 21.21 | 17166.81 | 6.28 | 107807.59 | 150 | 718.72 | 12 | 8.62 |
| P04 | 40.95 | 21.21 | 18421.93 | 6.28 | 115689.75 | 150 | 771.27 | 12 | 9.26 |
| P05 | 43.66 | 21.21 | 19641.07 | 6.28 | 123345.90 | 150 | 822.31 | 12 | 9.87 |
| **P06** | **319.6** | **21.21** | **143776.57** | **6.28** | **902916.84** | **150** | **6019.45** | **12** | **72.23** |
| P07 | 47.98 | 21.21 | 21584.48 | 6.28 | 135550.53 | 150 | 903.67 | 12 | 10.84 |
| P08 | 57.2 | 21.21 | 25732.23 | 6.28 | 161598.38 | 150 | 1077.32 | 12 | 12.93 |
| P09 | 60.4 | 21.21 | 27171.79 | 6.28 | 170638.85 | 150 | 1137.59 | 12 | 13.65 |
| P10 | 43.96 | 21.21 | 19776.03 | 6.28 | 124193.44 | 150 | 827.96 | 12 | 9.94 |
| P11 | 41.54 | 21.21 | 18687.35 | 6.28 | 117356.59 | 150 | 782.38 | 12 | 9.39 |

### 3.2 Average daily energy consumption of the light panels during daylight hours

Of all the panels sampled, P06 consumed the most energy, with a daily average of 72.23 kWh (See Table 2), probably because it has better brightness compared to the others of the same size. Energy consumption is closely related to luminous efficiency; for LED panels, this efficiency varies depending on the type of technology and manufacturing; for the research, an average efficiency of 150 lumens per watt (lm/W) was considered, based on advertising information from some manufacturers indicating that high-performance (high-quality) LEDs can reach efficiencies of up to 220 lm/W, for standard performance between 150 and 2000 lm/W, for good performance the efficiency is 100 to 149 lm/W, and for low performance the efficiency is less than 99 lm/W (Luministrips, 2021). For panel P06, it is recognized that it is a full-colour LED display, and it is known that these panels emit high brightness (between 5,500 and 8,000 cd), while their consumption can be between 400 and 700 W/m$^2$ due to the requirement to display complex multimedia content with high colour quality (Hytedisplay 2021).

Figures 1a and 1b identify illuminated panels that are on and illuminated panels that are off during daylight hours and installed in nearby locations. This allows us to compare and appreciate a certain similarity in the clarity and advertising visibility of both types of panels. In other words, without taking into account the advertising message (which of course has an influence), there is little difference in the visibility of these two types of panels. This fact allows us to establish that, except for panels that have a high level of brightness (for example, the P06), having the illuminated panels on during days with natural light would not have much advertising advantage; On the contrary, it would be a waste of energy. In Table 2, adding the energy consumed by the sample of all the light panels operating during the day, we have a total of 221.49 kWh that would be wasted to some extent.

For the 36 m$^2$ P06 panel, a power output of 6019.45 W was calculated, equivalent to 167.207 W per square meter. Considering 10 hours of operation, this would result in energy consumption of 1.67 kWh per square meter. The value calculated above is very similar to the results of a study for the Monochromatic 10-step LED panel type, which consumed 27 W, with 18 modules per square meter at a power of 500 W/m$^2$ when all panels were on. However, they consider that under normal conditions, only 35-50 % will be on. Therefore, they estimate an actual consumption of 175-250 W/m$^2$, which, for 10 hours of operation, has a consumption of 1.75 to 2.5 kWh per square meter (Hytedisplay, 2021). Therefore, the consumption of the P06 panel in this study is similar to the referenced study. The research based its calculation on luminance data, measurement distance, and panel size; Energy consumption could also be improved by using data on other specific characteristics of each LED panel (which in this case was not feasible due to commercial availability). Nevertheless, the study

represents progress and provides interesting results regarding environmental conservation, the impact of light pollution, energy expenditure, and greenhouse gas emissions that contribute to climate change.

### 3.3 Amount of $CO_2$ generated by energy consumption in the panels during the day

The Intergovernmental Panel on Climate Change (IPCC) indicates that the $CO_2$ generated per kWh consumed is related to the energy source; thus, corresponding to Coal: 820, Oil: 600, Natural gas: 490, Photovoltaic: 48, Hydroelectric: 24, Nuclear: 12 and Wind: 11 g $CO_2$ per kWh respectively (Williamson 2023). Table 3 shows the amount of $CO_2$ generated by each panel considering hydroelectric as the energy source, giving a total of 56,140.7 g of $CO_2$ per day.

*Table 3: $CO_2$ generation as an environmental impact due to energy consumption of light panels*

| | Light panels operating with hydroelectric power (generates 40 g of $CO_2$ per kWh) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | P01 | P02 | P03 | P04 | P05 | P06 | P07 | P08 | P09 | P10 | P11 |
| Energy consumed (kWh) | 53.11 | 11.65 | 8.62 | 9.26 | 9.87 | 72.23 | 10.84 | 12.93 | 13.65 | 9.94 | 9.39 |
| $CO_2$ generated per kWh (g) | 1274.71 | 279.57 | 206.99 | 222.12 | 236.82 | 1733.60 | 260.26 | 310.27 | 327.63 | 238.45 | 225.32 |
| Times on (h) | 6.00 | 12.00 | 12.00 | 12.00 | 12.00 | 12.00 | 12.00 | 12.00 | 12.00 | 12.00 | 12.00 |
| $CO_2$ diary (g) | 7648.2 | 3354.8 | 2483.9 | 2665.5 | 2841.9 | 20803.2 | 3123.1 | 3723.2 | 3931.5 | 2861.4 | 2703.9 |

Photovoltaics offer a sustainable and efficient solution (Rosu, et al., 2020) and can be used as a power feeder to luminous panels. With advances in photovoltaic materials, energy storage and smart control systems (Zedak, et al., 2019), would allow the development of the advertising industry in the environmental field in addition to economic advantages, although initially the installation cost may be high, in the long term photovoltaic systems can bring significant savings by reducing cost of electricity tariffs and maintenance, with advantage of autonomy of operation and reduction in consumption of fossil fuels, with a consequent decrease in greenhouse gases; this can become a sustainable business application (Ras D. and Sasmita S., 2024; Yu-Feng, L., 2025; Lim, et al., 2024). The use of green hydrogen is another alternative (Nkwambe, 2024).

## 4. Conclusion

It was determined that the operation of light panels during daylight hours, for the study sample, reaches from 8.62 kWh to 72.23 kWh per day; While it is true that LED panels have special characteristics that, due to their clarity, can attract the visual attention of customers looking for information, there are also environmental factors such as natural sunlight that cause the visibility of these panels to decrease and not have the impact that they do in the darkness of the night; Within this analysis, the energy consumed by light panels during daylight hours may constitute an unusable energy expense that could be saved, obtaining beneficial impacts mainly in favour of the environment, as well as economic; on the contrary, its consumption means a considerable impact on the generation of gases such as $CO_2$, a precursor to climate change, which in the sample of panels is a total of 56,140.7 g of $CO_2$ diary..

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