УНИВЕРЗИТЕТ У ИСТОЧНОМ САРАЈЕВУ
University of East Sarajevo

Assessment of Photovoltaic Panel Efficiency Under Different Spectral Characteristics of Artificial Lighting

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Abstract. The increasing use of photovoltaic (PV) systems in indoor and hybrid environments has raised the need to evaluate their performance under artificial lighting conditions. Unlike natural solar radiation, artificial light sources exhibit distinct spectral characteristics that significantly influence the energy conversion efficiency of photovoltaic panels. This paper presents an assessment of photovoltaic panel efficiency under different types of artificial lighting, with a particular focus on spectral power distribution effects. Experimental measurements were conducted using commonly applied artificial light sources, including LED, fluorescent, and incandescent lamps. The electrical output parameters of the PV panel, such as voltage, current, and power, were measured and compared under controlled illumination conditions. In parallel, the spectral characteristics of each light source were analyzed and correlated with the spectral response of the photovoltaic cell. The results indicate that photovoltaic efficiency under artificial lighting is highly dependent on spectral matching between the light source and the PV material.

The mathematical model of radiation from different artificial light sources can be expressed using the following equations. The radiation spectrum of an incandescent lamp can be accurately approximated by Planck's law of black-body radiation, as the tungsten filament behaves as a thermal emitter:

$$E_{inc}\left(\lambda,T\right)=\frac{2\pi hc^2}{\lambda^5}\cdot\frac{1}{\exp\left(\dfrac{hc}{\lambda kT}\right)-1}$$

The spectrum of a white LED is typically modeled as a superposition of multiple Gaussian components:

$$E_{LED}\left(\lambda\right)=E_0\exp\left[\frac{\left(\lambda-\lambda_0\right)^2}{2\sigma^2}\right]$$

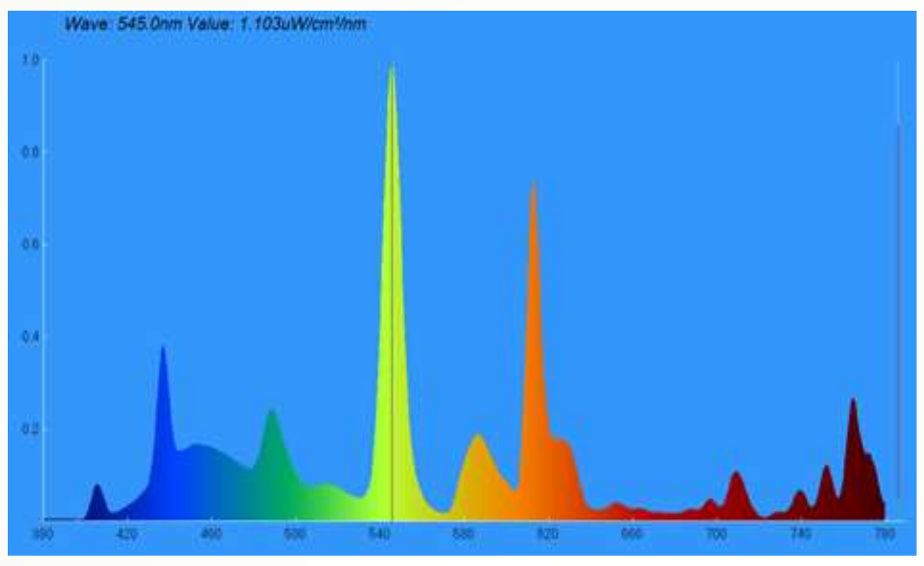

Fig.2. The spectral characteristics of a 25W fluorescent light sour

The spectral dependence of the solar cell is commonly expressed through the spectral short-circuit current density, which quantifies the contribution of photons at a given wavelength to the generated photocurrent. This dependence can be written as:

$$J_{sc}\left(\lambda\right)=q\cdot\Phi\left(\lambda\right)\cdot E_{QE}\left(\lambda\right)$$

$\boldsymbol{J_{sc}(\lambda)}$ is the spectral short-circuit current density [A/m²·nm], $\boldsymbol{q}$ is the elementary charge, $\boldsymbol{\Phi(\lambda)}$ is the incident photon flux density [photons/m²·s·nm], and $\boldsymbol{E_{QE}(\lambda)}$ is the external quantum efficiency of the solar cell.

The relationship between **spectral responsivity and external quantum efficiency** is given by:

$$E_{QE}\left(\lambda\right)=\frac{h\cdot c}{q\cdot\lambda}S_R\left(\lambda\right)$$

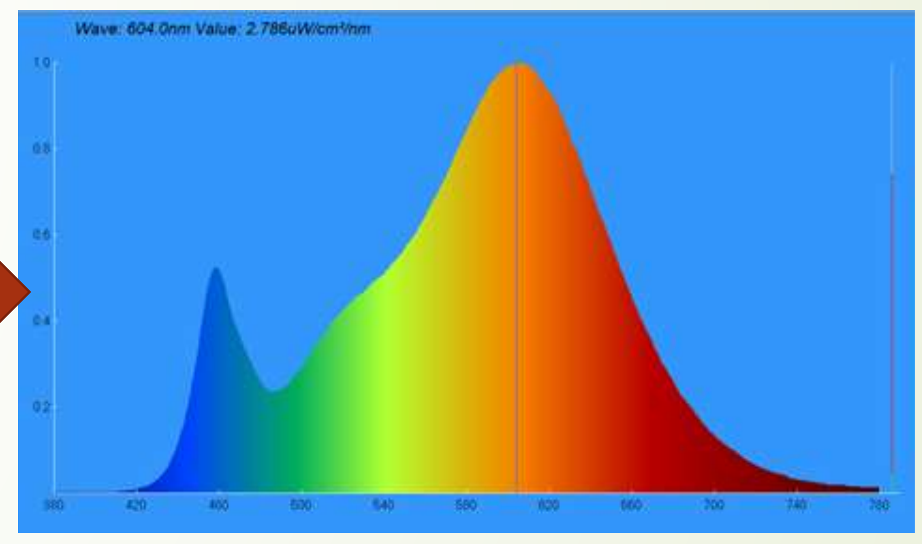

Fig.3 The spectral characteristics of a 15W LED light source

Experimental Results

The experimental setup included **incandescent, LE[illegible]nd fluorescent light sources**, an [illegible]**PCS-320 spectroradiometer**, and a **[illegible] photovoltaic module.**

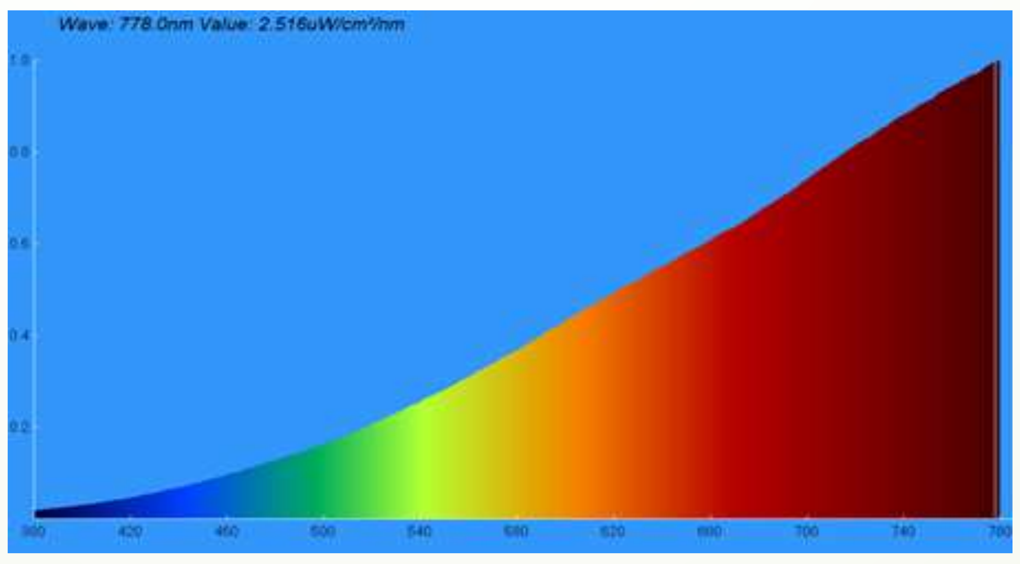

Fig.1. The spectral characteristics of a 100 W incandescent light source

For the experimental analysis, three artificial light sources with approximately the same luminous flux of **1600 lm** were selected in order to ensure comparable illumination conditions. Although the emitted light levels are similar, the electrical power ratings of the sources differ significantly.

For the experiment, a small photovoltaic module with an output voltage of **5 V**, a maximum current of **75 mA**, and a power of **0.375 W** was utilized. Figure shows the spectral response of the photovoltaic module.

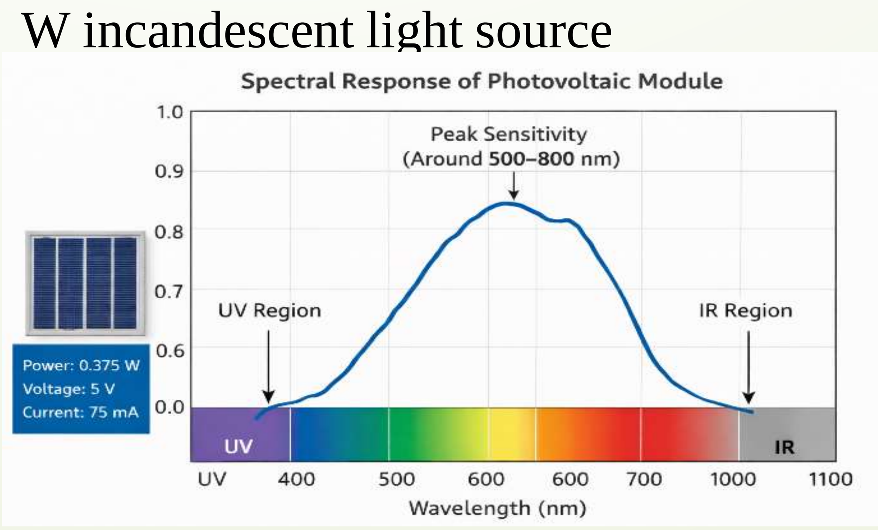

Table I. - The measured output voltage of the photovoltaic module

Distance (cm)	LED (V)	Fluorescent (V)	Incandescent (V)
10	3.83	2.47	4.15
20	2.88	1.77	4.11
30	2.65	1.44	4.00
40	2.47	1.20	3.81
50	2.46	1.09	3.60
150	1.15	0.90	2.47

Table II. - The measured output current of the photovoltaic module

Distance (cm)	LED (mA)	Fluorescent (mA)	Incandescent (mA)
10	0.89	0.25	0.98
20	0.80	0.14	0.97
30	0.63	0.10	0.91
40	0.48	0.07	0.87
50	0.27	0.04	0.18
150	0.07	0.01	0.46

The equipment shown in Figure was used for the experimental investigations.

Conclusion

This study assessed the effect of artificial light sources with different spectral characteristics on the energy conversion efficiency of a small photovoltaic module.

The main advantage of this approach is the ability to optimize indoor PV performance using tailored light sources, while a key limitation lies in the inherent dependency of efficiency on both spectrum and illuminance, which may vary in practical settings.