Digital communication installations

REPORTING OF THE MEASUREMENT CAMPAIGN AND ENERGY SAVINGS VERIFICATION

IN COMPLIANCE WITH IPMVP - *INTERNATIONAL PERFORMANCE MEASUREMENT AND VERIFICATION PROTOCOL*

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1. EXECUTIVE SUMMARY

Context

This document presents the results of a **measurement campaign of electrical parameters** in digital communication installations using RGB SMD LED technology, specifically:

- No. 1 outdoor LED wall installation (LED billboard)
- No. 1 indoor LED totem installation (shop window display)

Based on the measured electrical parameters, the active power absorbed was recorded using a power analyzer as a function of the chromatic configuration of raster images displayed on the installations.

Objective

The **objective of the measurement campaign** is to quantify the energy savings associated with design choices and the resulting color mixes of displayed images, assessing the impact of colors and their corresponding temperature values in RGB LEDs.

Measurement protocol

Energy savings reporting was carried out in accordance with the **International Performance Measurement and Verification Protocol (IPMVP)**, focusing on **Option A**, i.e. isolation of the system with measurement of key parameters.

Savings estimation methodology

In accordance with IPMVP Option A, it was necessary to identify the contribution of the main parameters influencing the energy performance of an LED wall, namely:

- **hardware and control system contribution**, which defines the current range supplying the LEDs and determines minimum and maximum brightness levels
- a further contribution is related to the color **value of each pixel/LED composing the displayed image**, represented by the Average Picture Level

(APL), a statistical metric expressing the average brightness of all pixels in a raster frame relative to a full white signal; an APL of 0% corresponds to a completely black screen, whereas an APL of 100% represents a uniformly white image at maximum signal level.

Energy savings were therefore evaluated in terms of the difference in electricity consumption between images displayed in a standard “bright” configuration, characterized by APL values above 50%, and images in a “dark” configuration, with APL values below 50%.

The measured data confirm an approximately linear relationship between the chromatic design of the images and the absorbed electrical power, with savings percentages reaching, for example, values exceeding 70% when moving from APL levels of 75% to 35%.

2. DESCRIPTION OF THE MEASUREMENT ACTIVITY

The measurement campaign was conducted on **March 13, 2026**, recording electrical parameters of two installations displaying image cycles with variable brightness levels.

Installation No. 1

- Location: Via Cadamosto 1, Corsico (MI)
- Indoor installation
- Measurement time: 10:30 – 13:00
- Description of the measured installation:
  - LED wall – SMD technology
  - Screen size: 2000 × 1000 mm
  - Resolution: 416 × 208 pixels (1 LED per pixel)
  - Pixel density: 43,403 pixels/m²
  - Pixel pitch: 4.8 mm
- Image display frequency: 10 s over a 10 min cycle
- Measurement frequency: 10 s

Installation No. 2

- Location: Corso Buenos Aires 1, Milan
- Indoor installation
- Measurement time: 16:45 – 19:00
- Description of the measured installation:
  - Indoor LED totem – SMD technology
  - Screen size: 640 × 1920 mm
  - Resolution: 256 × 768 pixels
  - Pixel density: 160,000 pixels/m²
  - Pixel pitch: 2.5 mm
- Image display frequency: 30 s over a 7 min 30 s cycle
- Measurement frequency: 10 s

For the determination of energy savings, the International Performance Measurement and Verification Protocol (IPMVP) was applied, specifically adopting Option A as defined by the protocol[1]: "isolation of the energy efficiency improvement activity with measurement of the key parameters." The application of Option A to the specific case defines the measurement boundary at the power supply cable of the device subject to the efficiency improvement activity and contemplates the measurement of the main parameter, namely the absorbed active electrical power.

[1] IPMVP Core Concepts – 2022

3. BASELINE AND REPORTING PERIOD CRITERIA

The typical operating cycle for the installations under consideration consists of the sequential display of images, with each individual image persisting for approximately several seconds and with the overall cycle duration varying depending on the number of images displayed.

In view of the purpose of the measurements, the criterion of contiguous measurement periods was adopted, with alternating measurements on display cycles in bright mode, assumed as the reference baseline, and measurements with the efficiency action activated, i.e. in dark configuration, for the same images and for display cycles of the same duration: in accordance with the IPMVP protocol, measurements in dark mode were therefore considered as reporting period measurements.

Based on the relevant technical literature and the bibliographic references provided in Chapter 10, the APL parameter, as defined in the introduction, was identified as the independent variable for determining savings: the technical literature confirms that, for self-emissive displays, there is an almost linear correlation between APL and electrical power demand.

The measurement activity was therefore carried out by recording the electrical power consumed during the display of images with varying APL values: the set of images to be used was provided by the Client, attached to this report, and the corresponding APL values in both bright and dark modes were calculated for each image displayed during the cycle.

4. CRITERIA FOR DEFINING ADJUSTMENT PARAMETERS

Adjustment parameters include factors that may influence the energy consumption or demand of the installation and that are systematically incorporated to determine the adjustment of the baseline during the reporting period, in order to enable comparison under the same conditions; specifically, the following dynamic parameters were considered:

- APL – identified as the independent variable
- duration of each display cycle: maintained constant

The following were considered as static adjustment parameters:

- installation surface area [m^2]
- installation pixel pitch (distance in millimetres between the centres of two adjacent pixels/LEDs on a screen) [mm]
- installation technology: RGB SMD LED
- environmental conditions during measurement, in particular temperature, humidity and illuminance, whose possible variations were considered negligible due to the rapid alternation between cycles under reference conditions and cycles under reporting conditions.

In order to account for the main identified static adjustment factors and to allow for a generalisation of the results—albeit limited to installations of the same technology—energy savings were calculated as the difference between the values of the electrical power index per square metre of surface area and per mm of pixel pitch [$kW/m^2/mm$] in bright and dark configurations, correlating it with the variation of the APL parameter of the displayed images.

5. SUMMARY OF COLLECTED DATA

The recorded raw data are collected in the file provided in Annex 1: the data were processed by grouping them according to the specific installation and the different chromatic configurations, evaluating the corresponding average values and the related statistical parameters in terms of confidence interval (uncertainty) and confidence level. With reference to the requirements for the application of the IPMVP protocol, a Student's t statistical distribution was considered, with a standard confidence level of 68.3% (t = 1) and a confidence level of 90% (t = 1.64)[2].

[2] EVO Uncertainty assessment for IPMVP - 2019

Installation No. 1

The purpose of the measurements carried out on Installation No. 1 was to establish the actual evidence of the two main contributing factors to energy demand, as defined in the introduction to this document.

To summarise the measurements performed on Installation No. 1, the following graph illustrates the variation of specific electrical power during the different display cycles of the image set, characterised by varying APL values: the trends obtained by setting the maximum brightness setpoint managed by the billboard driver to three different values, namely 100%, 50%, and 5%, are superimposed (for ease of reading, the graph is shown on the following page).

The graph is presented to support the following assumption: the variation of the maximum brightness level set for the billboard clearly affects the energy demand; however, the influence due to variations in the APL parameter value remains evident, determining the peak and valley trends observed in the graphs.

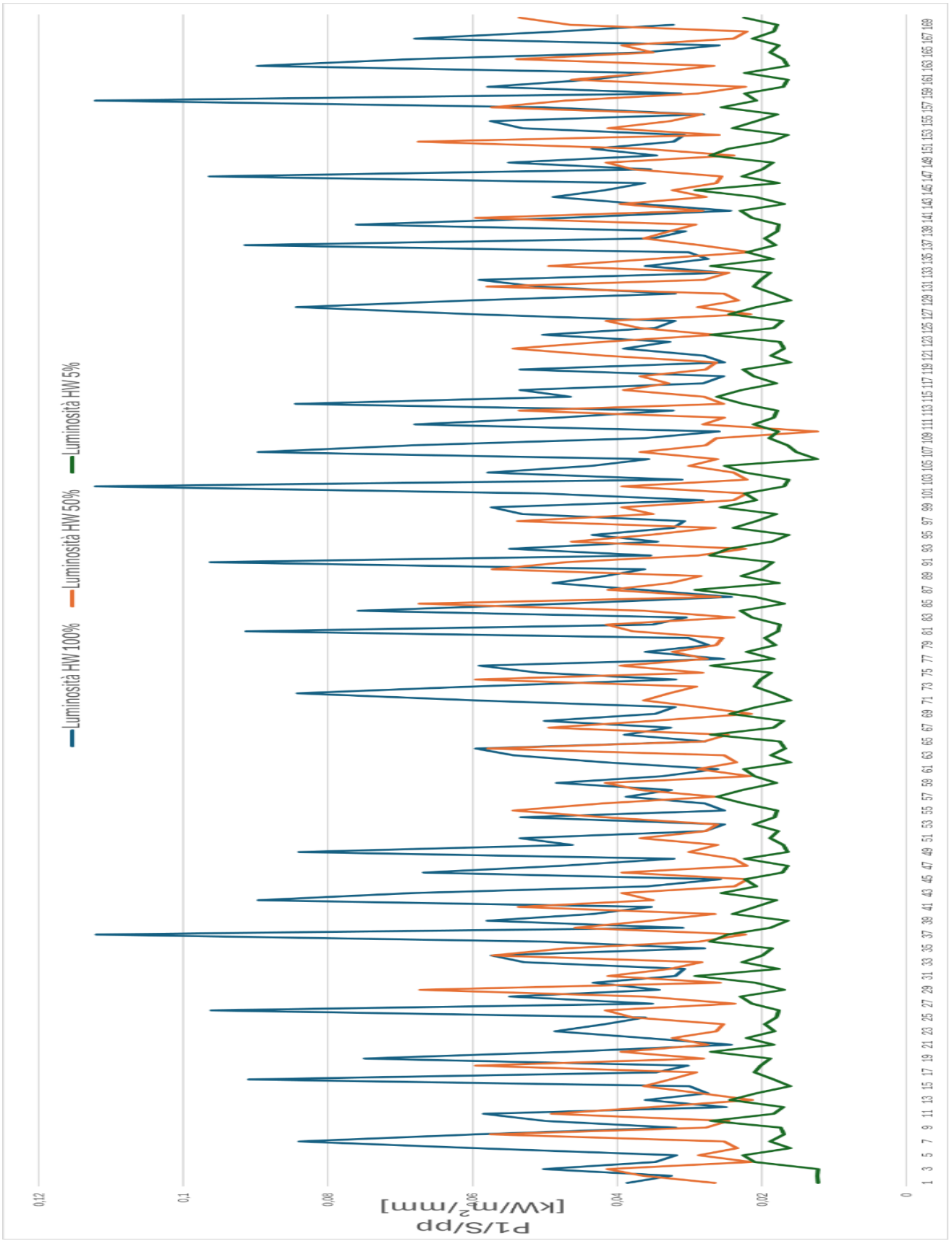

Fig. 1 – Specific power measurement – Installation No. 1

The results of the statistical analysis of the reduction in energy demand as a function of the maximum brightness level controlled by the billboard driver are summarised below:

- **Maximum brightness 100%**

Average consumption		**0,04686**	**kW/m²/mm**
Instrument accuracy		1%	
Variance		0,00041	
Standard deviation		0,02016	kW/m²/mm
Standard error		0,00154	kW/m²/mm
Percentage standard error		3,289%	
Degrees of freedom		170	
tStudent	90%	1,64	
Uncertainty	**±**	**0,01031**	**kW/m²/mm**

- **Maximum brightness 50%**

Average consumption		**0,03443**	**kW/m²/mm**
Instrument accuracy		1%	
Variance		0,00012	
Standard deviation		0,01108	kW/m²/mm
Standard error		0,00085	kW/m²/mm
Percentage standard error		2,467%	
Degrees of freedom		169	
tStudent	90%	1,64	
Uncertainty	**±**	**0,0101**	**kW/m²/mm**

- **Maximum brightness 5%**

Average consumption		**0,02012**	**kW/m²/mm**
Instrument accuracy		1%	
Variance		0,00001	
Standard deviation		0,00344	kW/m²/mm
Standard error		0,00026	kW/m²/mm
Percentage standard error		1,313%	
Degrees of freedom		169	
tStudent	90%	1,64	
Uncertainty	**±**	**0,01001**	**kW/m²/mm**

The highlighted statistical uncertainty values, of the same order of magnitude as the average consumption values, confirm the dependence of energy consumption on the APL parameter, whose correlation was the subject of the measurements carried out with installation no. 2.

Installation no. 2

The measurements at installation 2 were recorded keeping the maximum brightness managed by the LEDwall driver constant, with cyclic display of the same set of images, attached to this document, available in bright mode, characterised by APL values above 50%, and in dark mode, defined by APL values below 50%. The table below shows the recorded data for absorbed electrical power, the APL value of the corresponding image, and the corresponding specific power value P/S/pp:

Date	Time	P	Unit	APL	P/S/pp [kW/m²/mm]
13/03/2026	17:01:36	0,251	kW	0,54	0,081706
13/03/2026	17:01:46	0,251	kW	0,52	0,081706
13/03/2026	17:01:56	0,251	kW	0,57	0,081706
13/03/2026	17:02:06	0,239	kW	0,51	0,077799
13/03/2026	17:02:16	0,251	kW	0,52	0,081706
13/03/2026	17:02:26	0,250	kW	0,52	0,081380

13/03/2026	17:02:36	0,254	kW	0,61	0,082682
13/03/2026	17:02:46	0,383	kW	0,71	0,124674
13/03/2026	17:02:56	0,383	kW	0,71	0,124674
13/03/2026	17:03:06	0,382	kW	0,71	0,124349
13/03/2026	17:03:16	0,269	kW	0,63	0,087565
13/03/2026	17:03:26	0,269	kW	0,63	0,087565
13/03/2026	17:03:36	0,269	kW	0,63	0,087565
13/03/2026	17:03:46	0,277	kW	0,65	0,090169
13/03/2026	17:03:56	0,277	kW	0,65	0,090169
13/03/2026	17:04:06	0,276	kW	0,65	0,089844
13/03/2026	17:04:16	0,602	kW	0,76	0,195964
13/03/2026	17:04:26	0,600	kW	0,76	0,195313
13/03/2026	17:04:36	0,601	kW	0,76	0,195638
13/03/2026	17:04:46	0,56	kW	0,73	0,182292
13/03/2026	17:04:56	0,559	kW	0,73	0,181966
13/03/2026	17:05:06	0,560	kW	0,73	0,182292
13/03/2026	17:05:16	0,250	kW	0,52	0,081380
13/03/2026	17:05:26	0,251	kW	0,52	0,081706
13/03/2026	17:05:36	0,252	kW	0,54	0,082031
13/03/2026	17:05:46	0,251	kW	0,52	0,081706
13/03/2026	17:05:56	0,251	kW	0,57	0,081706
13/03/2026	17:06:06	0,251	kW	0,56	0,081706
13/03/2026	17:06:16	0,252	kW	0,56	0,082031

13/03/2026	17:06:26	0,251	kW	0,55	0,081706
13/03/2026	17:06:36	0,252	kW	0,56	0,082031
13/03/2026	17:06:46	0,383	kW	0,71	0,124674
13/03/2026	17:06:56	0,382	kW	0,71	0,124349
13/03/2026	17:07:06	0,383	kW	0,71	0,124674
13/03/2026	17:07:16	0,269	kW	0,63	0,087565
13/03/2026	17:07:26	0,269	kW	0,63	0,087565
13/03/2026	17:07:36	0,270	kW	0,63	0,087891
13/03/2026	17:07:46	0,277	kW	0,65	0,090169
13/03/2026	17:07:56	0,277	kW	0,65	0,090169
13/03/2026	17:08:06	0,277	kW	0,65	0,090169
13/03/2026	17:08:16	0,601	kW	0,76	0,195638
13/03/2026	17:08:26	0,599	kW	0,76	0,194987
13/03/2026	17:08:36	0,601	kW	0,76	0,195638
13/03/2026	17:08:46	0,560	kW	0,73	0,182292
13/03/2026	17:08:56	0,558	kW	0,73	0,181641
13/03/2026	17:09:06	0,560	kW	0,73	0,182292
13/03/2026	17:09:16	0,250	kW	0,52	0,081380
13/03/2026	17:09:26	0,251	kW	0,52	0,081706
13/03/2026	17:09:36	0,251	kW	0,54	0,081706
13/03/2026	17:09:46	0,251	kW	0,57	0,081706
13/03/2026	17:09:56	0,251	kW	0,56	0,081706
13/03/2026	17:10:06	0,252	kW	0,56	0,082031

13/03/2026	17:10:16	0,250	kW	0,55	0,081380
13/03/2026	17:10:26	0,251	kW	0,55	0,081706
13/03/2026	17:10:36	0,251	kW	0,52	0,081706
13/03/2026	17:10:46	0,383	kW	0,71	0,124674
13/03/2026	17:10:56	0,383	kW	0,71	0,124674
13/03/2026	17:11:06	0,383	kW	0,71	0,124674
13/03/2026	17:11:16	0,270	kW	0,63	0,087891
13/03/2026	17:11:26	0,268	kW	0,63	0,087240
13/03/2026	17:11:36	0,268	kW	0,63	0,087240
13/03/2026	17:11:46	0,276	kW	0,65	0,089844
13/03/2026	17:11:56	0,277	kW	0,65	0,090169
13/03/2026	17:12:06	0,277	kW	0,65	0,090169
13/03/2026	17:12:16	0,601	kW	0,76	0,195638
13/03/2026	17:12:26	0,60	kW	0,76	0,195313
13/03/2026	17:12:36	0,60	kW	0,76	0,195313
13/03/2026	17:12:46	0,560	kW	0,73	0,182292
13/03/2026	17:12:56	0,560	kW	0,73	0,182292
13/03/2026	17:13:06	0,560	kW	0,73	0,182292
13/03/2026	17:13:16	0,251	kW	0,52	0,081706
13/03/2026	17:13:26	0,252	kW	0,54	0,082031
13/03/2026	17:13:36	0,251	kW	0,57	0,081706
13/03/2026	17:13:46	0,252	kW	0,56	0,082031
13/03/2026	17:13:56	0,252	kW	0,56	0,082031

13/03/2026	17:14:06	0,251	kW	0,55	0,081706
13/03/2026	17:14:16	0,251	kW	0,55	0,081706
13/03/2026	17:14:26	0,251	kW	0,52	0,081706
13/03/2026	17:14:36	0,251	kW	0,52	0,081706
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13/03/2026	17:14:56	0,383	kW	0,71	0,124674
13/03/2026	17:15:06	0,382	kW	0,71	0,124349
13/03/2026	17:15:16	0,269	kW	0,63	0,087565
13/03/2026	17:15:26	0,269	kW	0,63	0,087565
13/03/2026	17:15:36	0,269	kW	0,63	0,087565
13/03/2026	17:15:46	0,277	kW	0,65	0,090169
13/03/2026	17:15:56	0,278	kW	0,65	0,090495
13/03/2026	17:16:06	0,276	kW	0,65	0,089844
13/03/2026	17:16:16	0,602	kW	0,76	0,195964
13/03/2026	17:16:26	0,600	kW	0,76	0,195313
13/03/2026	17:16:36	0,602	kW	0,76	0,195964
13/03/2026	17:16:46	0,560	kW	0,73	0,182292
13/03/2026	17:16:56	0,560	kW	0,73	0,182292
13/03/2026	17:17:06	0,561	kW	0,73	0,182617
13/03/2026	17:17:16	0,251	kW	0,52	0,081706
13/03/2026	17:17:26	0,251	kW	0,54	0,081706
13/03/2026	17:17:36	0,252	kW	0,57	0,082031
13/03/2026	17:17:46	0,251	kW	0,56	0,081706

13/03/2026	17:17:56	0,251	kW	0,56	0,081706
13/03/2026	17:18:06	0,251	kW	0,55	0,081706
13/03/2026	17:18:16	0,251	kW	0,55	0,081706
13/03/2026	17:18:26	0,252	kW	0,52	0,082031
13/03/2026	17:18:36	0,251	kW	0,52	0,081706
13/03/2026	17:18:46	0,384	kW	0,71	0,125000
13/03/2026	17:18:56	0,383	kW	0,71	0,124674
13/03/2026	17:19:06	0,383	kW	0,71	0,124674
13/03/2026	17:19:16	0,269	kW	0,63	0,087565
13/03/2026	17:19:26	0,269	kW	0,63	0,087565
13/03/2026	17:19:36	0,269	kW	0,63	0,087565
13/03/2026	17:19:46	0,277	kW	0,65	0,090169
13/03/2026	17:19:56	0,278	kW	0,65	0,090495
13/03/2026	17:20:06	0,277	kW	0,65	0,090169
13/03/2026	17:20:16	0,600	kW	0,76	0,195313
13/03/2026	17:20:26	0,601	kW	0,76	0,195638
13/03/2026	17:20:36	0,600	kW	0,76	0,195313
13/03/2026	17:20:46	0,560	kW	0,73	0,182292
13/03/2026	17:20:56	0,559	kW	0,73	0,181966
13/03/2026	17:21:06	0,560	kW	0,73	0,182292
13/03/2026	17:21:16	0,251	kW	0,52	0,081706
13/03/2026	17:21:26	0,251	kW	0,54	0,081706
13/03/2026	17:21:36	0,252	kW	0,57	0,082031

13/03/2026	17:21:46	0,252	kW	0,56	0,082031
13/03/2026	17:21:56	0,251	kW	0,56	0,081706
13/03/2026	17:22:06	0,251	kW	0,55	0,081706
13/03/2026	17:22:16	0,252	kW	0,55	0,082031
13/03/2026	17:22:26	0,251	kW	0,52	0,081706
13/03/2026	17:22:36	0,251	kW	0,52	0,081706
13/03/2026	17:22:46	0,384	kW	0,71	0,125000
13/03/2026	17:22:56	0,383	kW	0,71	0,124674
13/03/2026	17:23:06	0,383	kW	0,71	0,124674
13/03/2026	17:23:16	0,269	kW	0,63	0,087565
13/03/2026	17:23:26	0,269	kW	0,63	0,087565
13/03/2026	17:23:36	0,269	kW	0,63	0,087565
13/03/2026	17:23:46	0,277	kW	0,65	0,090169
13/03/2026	17:23:56	0,277	kW	0,65	0,090169
13/03/2026	17:24:06	0,277	kW	0,65	0,090169
13/03/2026	17:24:16	0,601	kW	0,76	0,195638
13/03/2026	17:24:26	0,600	kW	0,76	0,195313
13/03/2026	17:24:36	0,599	kW	0,76	0,194987
13/03/2026	17:24:46	0,559	kW	0,73	0,181966
13/03/2026	17:24:56	0,560	kW	0,73	0,182292
13/03/2026	17:25:06	0,560	kW	0,73	0,182292
13/03/2026	17:25:16	0,250	kW	0,52	0,081380
13/03/2026	17:25:26	0,252	kW	0,54	0,082031

13/03/2026	17:25:36	0,251	kW	0,57	0,081706
13/03/2026	17:25:46	0,251	kW	0,56	0,081706
13/03/2026	17:25:56	0,251	kW	0,56	0,081706
13/03/2026	17:26:06	0,251	kW	0,55	0,081706
13/03/2026	17:26:16	0,252	kW	0,55	0,082031
13/03/2026	17:26:26	0,251	kW	0,52	0,081706
13/03/2026	17:26:36	0,252	kW	0,58	0,082031
13/03/2026	17:26:46	0,384	kW	0,71	0,125000
13/03/2026	17:26:56	0,383	kW	0,71	0,124674
13/03/2026	17:27:06	0,384	kW	0,71	0,125000
13/03/2026	17:27:16	0,269	kW	0,63	0,087565
13/03/2026	17:27:26	0,268	kW	0,63	0,087240
13/03/2026	17:27:36	0,269	kW	0,63	0,087565
13/03/2026	17:27:46	0,277	kW	0,65	0,090169
13/03/2026	17:27:56	0,277	kW	0,65	0,090169
13/03/2026	17:28:06	0,277	kW	0,65	0,090169
13/03/2026	17:28:16	0,601	kW	0,76	0,195638
13/03/2026	17:28:26	0,601	kW	0,76	0,195638
13/03/2026	17:28:36	0,601	kW	0,76	0,195638
13/03/2026	17:28:46	0,560	kW	0,73	0,182292
13/03/2026	17:28:56	0,560	kW	0,73	0,182292
13/03/2026	17:29:06	0,560	kW	0,73	0,182292
13/03/2026	17:29:16	0,251	kW	0,57	0,081706

13/03/2026	17:29:26	0,250	kW	0,52	0,081380
13/03/2026	17:29:36	0,252	kW	0,57	0,082031
13/03/2026	17:29:46	0,251	kW	0,56	0,081706
13/03/2026	17:29:56	0,251	kW	0,56	0,081706
13/03/2026	17:30:06	0,251	kW	0,55	0,081706
13/03/2026	17:30:16	0,251	kW	0,55	0,081706
13/03/2026	17:30:26	0,251	kW	0,54	0,081706
13/03/2026	17:37:21	0,100	kW	0,33	0,032552
13/03/2026	17:37:31	0,101	kW	0,33	0,032878
13/03/2026	17:37:41	0,101	kW	0,33	0,032878
13/03/2026	17:37:51	0,141	kW	0,34	0,045898
13/03/2026	17:38:01	0,141	kW	0,34	0,045898
13/03/2026	17:38:11	0,141	kW	0,34	0,045898
13/03/2026	17:38:21	0,141	kW	0,33	0,045898
13/03/2026	17:38:31	0,141	kW	0,33	0,045898
13/03/2026	17:38:41	0,14	kW	0,33	0,045573
13/03/2026	17:38:51	0,141	kW	0,35	0,045898
13/03/2026	17:39:01	0,141	kW	0,35	0,045898
13/03/2026	17:39:11	0,141	kW	0,35	0,045898
13/03/2026	17:39:21	0,142	kW	0,35	0,046224
13/03/2026	17:39:31	0,141	kW	0,35	0,045898
13/03/2026	17:39:41	0,142	kW	0,35	0,046224
13/03/2026	17:39:51	0,148	kW	0,39	0,048177

13/03/2026	17:40:01	0,148	kW	0,39	0,048177
13/03/2026	17:40:11	0,146	kW	0,39	0,047526
13/03/2026	17:40:21	0,169	kW	0,40	0,055013
13/03/2026	17:40:31	0,169	kW	0,40	0,055013
13/03/2026	17:40:41	0,169	kW	0,40	0,055013
13/03/2026	17:40:51	0,185	kW	0,41	0,060221
13/03/2026	17:41:01	0,184	kW	0,41	0,059896
13/03/2026	17:41:11	0,185	kW	0,41	0,060221
13/03/2026	17:41:21	0,098	kW	0,33	0,031901
13/03/2026	17:41:31	0,098	kW	0,33	0,031901
13/03/2026	17:41:41	0,098	kW	0,33	0,031901
13/03/2026	17:41:51	0,100	kW	0,33	0,032552
13/03/2026	17:42:01	0,100	kW	0,33	0,032552
13/03/2026	17:42:11	0,100	kW	0,33	0,032552
13/03/2026	17:42:21	0,140	kW	0,34	0,045573
13/03/2026	17:42:31	0,139	kW	0,34	0,045247
13/03/2026	17:42:41	0,140	kW	0,34	0,045573
13/03/2026	17:42:51	0,139	kW	0,34	0,045247
13/03/2026	17:43:01	0,139	kW	0,34	0,045247
13/03/2026	17:43:11	0,139	kW	0,34	0,045247
13/03/2026	17:43:21	0,139	kW	0,34	0,045247
13/03/2026	17:43:31	0,139	kW	0,34	0,045247
13/03/2026	17:43:41	0,139	kW	0,34	0,045247

13/03/2026	17:43:51	0,140	kW	0,35	0,045573
13/03/2026	17:44:01	0,141	kW	0,35	0,045898
13/03/2026	17:44:11	0,140	kW	0,35	0,045573
13/03/2026	17:44:21	0,147	kW	0,39	0,047852
13/03/2026	17:44:31	0,146	kW	0,39	0,047526
13/03/2026	17:44:41	0,146	kW	0,39	0,047526
13/03/2026	17:44:51	0,168	kW	0,40	0,054688
13/03/2026	17:45:01	0,168	kW	0,40	0,054688
13/03/2026	17:45:11	0,168	kW	0,40	0,054688
13/03/2026	17:45:21	0,184	kW	0,41	0,059896
13/03/2026	17:45:31	0,183	kW	0,41	0,059570
13/03/2026	17:45:41	0,183	kW	0,41	0,059570
13/03/2026	17:45:51	0,096	kW	0,33	0,031250
13/03/2026	17:46:01	0,096	kW	0,33	0,031250
13/03/2026	17:46:11	0,097	kW	0,33	0,031576
13/03/2026	17:46:21	0,099	kW	0,33	0,032227
13/03/2026	17:46:31	0,100	kW	0,33	0,032552
13/03/2026	17:46:41	0,099	kW	0,33	0,032227
13/03/2026	17:46:51	0,139	kW	0,34	0,045247
13/03/2026	17:47:01	0,139	kW	0,34	0,045247
13/03/2026	17:47:11	0,138	kW	0,34	0,044922
13/03/2026	17:47:21	0,138	kW	0,34	0,044922
13/03/2026	17:47:31	0,138	kW	0,34	0,044922

13/03/2026	17:47:41	0,138	kW	0,34	0,044922
13/03/2026	17:47:51	0,138	kW	0,34	0,044922
13/03/2026	17:48:01	0,139	kW	0,34	0,045247
13/03/2026	17:48:11	0,138	kW	0,34	0,044922
13/03/2026	17:48:21	0,140	kW	0,35	0,045573
13/03/2026	17:48:31	0,140	kW	0,35	0,045573
13/03/2026	17:48:41	0,140	kW	0,35	0,045573
13/03/2026	17:48:51	0,145	kW	0,39	0,047201
13/03/2026	17:49:01	0,145	kW	0,39	0,047201
13/03/2026	17:49:11	0,145	kW	0,39	0,047201
13/03/2026	17:49:21	0,167	kW	0,40	0,054362
13/03/2026	17:49:31	0,167	kW	0,40	0,054362
13/03/2026	17:49:41	0,167	kW	0,40	0,054362
13/03/2026	17:49:51	0,183	kW	0,41	0,059570
13/03/2026	17:50:01	0,182	kW	0,41	0,059245
13/03/2026	17:50:11	0,182	kW	0,41	0,059245
13/03/2026	17:50:21	0,096	kW	0,33	0,031250
13/03/2026	17:50:31	0,096	kW	0,33	0,031250
13/03/2026	17:50:41	0,095	kW	0,33	0,030924
13/03/2026	17:50:51	0,099	kW	0,33	0,032227
13/03/2026	17:51:01	0,099	kW	0,33	0,032227
13/03/2026	17:51:11	0,096	kW	0,33	0,031250
13/03/2026	17:51:21	0,138	kW	0,35	0,044922

13/03/2026	17:51:31	0,138	kW	0,35	0,044922
13/03/2026	17:51:41	0,138	kW	0,35	0,044922
13/03/2026	17:51:51	0,137	kW	0,35	0,044596
13/03/2026	17:52:01	0,138	kW	0,35	0,044922
13/03/2026	17:52:11	0,138	kW	0,35	0,044922
13/03/2026	17:52:21	0,137	kW	0,36	0,044596
13/03/2026	17:52:31	0,137	kW	0,36	0,044596
13/03/2026	17:52:41	0,138	kW	0,36	0,044922
13/03/2026	17:52:51	0,139	kW	0,37	0,045247
13/03/2026	17:53:01	0,139	kW	0,37	0,045247
13/03/2026	17:53:11	0,139	kW	0,37	0,045247
13/03/2026	17:53:21	0,145	kW	0,39	0,047201
13/03/2026	17:53:31	0,145	kW	0,39	0,047201
13/03/2026	17:53:41	0,145	kW	0,39	0,047201
13/03/2026	17:53:51	0,167	kW	0,40	0,054362
13/03/2026	17:54:01	0,167	kW	0,40	0,054362
13/03/2026	17:54:11	0,167	kW	0,40	0,054362
13/03/2026	17:54:21	0,183	kW	0,41	0,059570
13/03/2026	17:54:31	0,181	kW	0,41	0,058919
13/03/2026	17:54:41	0,182	kW	0,41	0,059245
13/03/2026	17:54:51	0,095	kW	0,34	0,030924
13/03/2026	17:55:01	0,096	kW	0,34	0,031250
13/03/2026	17:55:11	0,096	kW	0,34	0,031250

13/03/2026	17:55:21	0,098	kW	0,35	0,031901
13/03/2026	17:55:31	0,098	kW	0,35	0,031901
13/03/2026	17:55:41	0,099	kW	0,35	0,032227
13/03/2026	17:55:51	0,137	kW	0,36	0,044596
13/03/2026	17:56:01	0,137	kW	0,36	0,044596
13/03/2026	17:56:11	0,138	kW	0,36	0,044922
13/03/2026	17:56:21	0,137	kW	0,37	0,044596
13/03/2026	17:56:31	0,137	kW	0,37	0,044596
13/03/2026	17:56:41	0,137	kW	0,37	0,044596
13/03/2026	17:56:51	0,137	kW	0,38	0,044596
13/03/2026	17:57:01	0,137	kW	0,38	0,044596
13/03/2026	17:57:11	0,138	kW	0,38	0,044922
13/03/2026	17:57:21	0,139	kW	0,39	0,045247
13/03/2026	17:57:31	0,139	kW	0,39	0,045247
13/03/2026	17:57:41	0,138	kW	0,39	0,044922
13/03/2026	17:57:51	0,145	kW	0,39	0,047201
13/03/2026	17:58:01	0,144	kW	0,39	0,046875
13/03/2026	17:58:11	0,144	kW	0,39	0,046875
13/03/2026	17:58:21	0,167	kW	0,40	0,054362
13/03/2026	17:58:31	0,167	kW	0,40	0,054362

Tab. 1 - Specific power - APL correlation

The chart below shows the distribution of the value pairs (APL, Specific power) and the corresponding linear regression line; the equation of the correlation model

between specific electrical power per unit area of the billboard and per mm of pixel pitch, correlated to the APL parameter value, can be described as follows:

P/S/pp [kW/m²/mm] = 0,2908 * APL - 0,0663

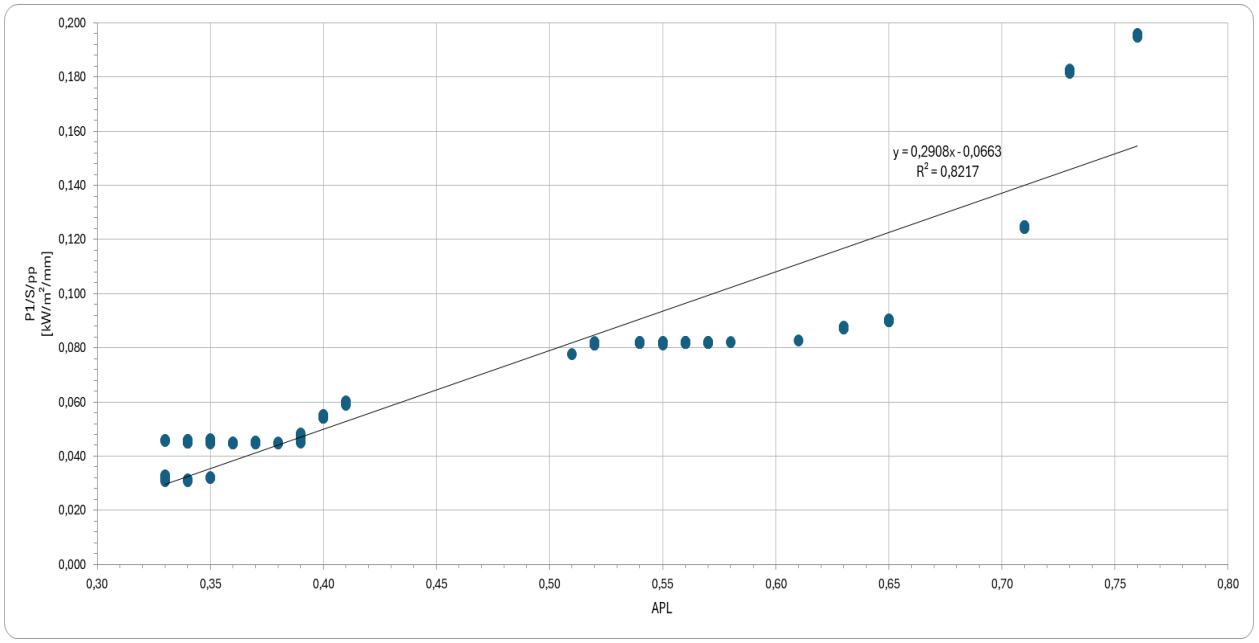

Fig. 2 - Specific power – APL correlation

The statistical parameters confirming the validity of the correlation are as follows:

Regression statistics	
Multiple R	0,9064689314
R Square	**0,8216859236**
Adjusted R Square	0,8210915433
Standard Error	0,02043355692
Observations	302

ANALYSIS OF VARIANCE

	gdl	*SQ*	*MQ*	*F*	*Significance F*
Regression	1	0,5772041133	0,5772041133	1382,424663	0
Residual	300	0,1252590746	0,0004175302486		
Total	301	0,7024631879			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 90.0%*	*Upper 90.0%*
Intercept	-0,06630875991	0,004237424921	-15,64836219	0	-0,07464760117	-0,05796991865	-0,07330029354	-0,05931722628
Variable X 1	0,2908079041	0,007821417519	37,18097179	0	0,275416113	0,3061996952	0,2779029667	0,3037128416

t-Student	1,649931694

The t-Student parameter value confirms a 90% confidence level.

6. ENERGY SAVING CALCULATION ALGORITHMS

To allow better generalisation of the results, energy saving has been assessed in terms of the avoided absorbed active power index per unit area of the installation and per unit of distance between the centres of 2 adjacent pixels, in the dark configuration compared to the reference bright configuration.

During the measurements, the contiguous periods method was used, i.e. performance was measured by alternating cycles in the activation state with cycles in the deactivation state of the efficiency measure:

- for measurements on installation 2:

$$\text{Specific active power reduction}_{\text{dark mode}} = EPI_{\text{ref,bright mode}} - EPI_{\text{rep,dark mode}}$$

where:

$EPI_{ref,bright\ mode}$ = Reference energy performance indicator in bright configuration [kW/m²/mm]

$EPI_{rep,dark\ mode}$ = Reporting energy performance indicator in dark configuration [kW/m²/mm]

Using the correlation model between specific power and APL, it is possible to assess energy saving for LED billboard installations as the APL parameter of an image varies. Two assessment examples are provided below, assuming the following values:

Installation dimensions 6096 x 3048 mm, area 18.58 m²

Pixel pitch: 4.8 mm

Bright image – APL 70%

- Specific power: 0.137 kW/m²/mm
- Total power: 0,137* 18,58 * 4,8 = 12,22 kW

For dark image – APL 35%

- Specific power: 0.035 kW/m²/mm

- Total power: 0.035* 18.58* 4.8 = 3.12 kW

Saving [%]: [(12,22 - 3,12) / 12,22] * 100 ≈ **74%**

Installation dimensions 3000 x 2000 mm, area 6.00 m²

Pixel pitch: 4.8 mm

Bright image – APL 70%

- Specific power: 0.137 kW/m²/mm
- Total power: 0,137 * 6,00 * 4,8 = 3,95 kW

For dark image – APL 35%

- Specific power: 0,035 kW/m²/mm
- Total power: 0,035 * 6,00 * 4,8 = 1,01 kW

Saving [%]: [(3,95 - 1,01) / 3,95] * 100 ≈ **74%**

7. MEASURING INSTRUMENTS USED

Electrical parameter measurements were taken using a PCE Instruments network analyser, model PA 8000, serial number A1109033, calibration certificate Kiwa Cermet Italia S.p.A. no. 00001LAT 2603979ESI.

The analyser measures the true RMS value of electrical parameters by integrating the actual waveform, regardless of its distortion.

8. MONITORING MANAGER

Overall responsibility for this Plan and its implementation is assigned to: Eng. Massimo Bottacini – Energy Management Expert certified Secem no. 0107-SC-EGE-2016 – Performance Measurement and Verification Analyst certified EVO-0839733232MB.

9. PROCEDURE FOR MONITORING PLAN VALIDITY OVER TIME

The procedure for monitoring the validity of the IPMVP plan over time is an iterative process requiring ongoing commitment from all parties involved, and includes the following steps:

- training of personnel involved in the project to carry out measurement and verification activities
- regular maintenance of measuring instruments
- continuous monitoring of data on the installation's energy variables
- data quality verification, to identify any errors or anomalies
- calibration verification of the installation's energy model using measured data
- updating the plan to account for any changes in operating conditions and reference regulations
- updating of indicators
- documentation of data and analyses in a clear and transparent manner.

10. REGULATORY AND BIBLIOGRAPHIC REFERENCES

- Regulatory references

  UNI CEI EN 17267:2019 Measurement and monitoring plan – Design and implementation – Principles for energy data collection

  UNI ISO 50006:2015 Energy management systems – Measurement of energy performance using energy baselines (EnB) and energy performance indicators (EnPI) – General principles and guidance

  UNI ISO 50015:2015 Energy management systems – Measurement and verification of energy performance of organisations – General principles and guidance

- References to the IPMVP protocol

  EVO IPMVP Core Concepts 2022

  EVO Uncertainty Assessment for IPMVP Application Guide 2019

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11. ANNEXES

1. Raw data source sheet
2. Processed data sheet
3. Technical data sheets of the measured installations
4. Folder containing the images used for the measurement
5. Current PMVA certificate of the author of this document
6. Generalisation of results