Lighting Solutions to Improve the Valorisation and Fruition of the Parque del Retiro in Madrid

To cite this article: Davide Carleo *et al* 2021 *IOP Conf. Ser.: Mater. Sci. Eng.* **1203** 022083

Lighting Solutions to Improve the Valorisation and Fruition of the Parque del Retiro in Madrid

Davide Carleo[1], Martina Gargiulo[1], Michelangelo Scorpio[1], Giovanni Ciampi[1], Luigi Corniello[1], Yorgos Spanodimitriou[1], Sergio Sibilio[1], Pilar Chìas[2]

[1] Department of Architecture and Industrial Design, University of Campania Luigi Vanvitelli, via San Lorenzo, 81031 Aversa (CE), Italy
[2] Escuela de Arquitectura, Universidad de Alcalà, Calle Sta. Úrsula, 8, 28801 Alcalà de Henares, Spain

yorgos.spanodimitriou@unicampania.it

Abstract. The lighting design of public spaces, and in particular of green areas, is becoming a growing interest in the contemporary culture, as more and more people are starting to enjoy cities at nighttime. In this study, the lighting design for two main areas of the Parque del Retiro in Madrid (Spain), the Puerta de España and the Paseo de las Estatuas de Reyes, is discussed. Two different lighting scenarios have been designed by means of the software DIALux evo, the first one with the aim of maximise the lighting effect and the second one with the aim to optimize the energy consumption while still allowing for the enhancement of the key characteristics of the two areas. A combined lighting design solution, obtained by using the two scenarios in a weekly schedule, allowed to achieve adequate levels of illumination, an improvement in the feeling of safety in visitors while optimizing energy consumption.

1. Introduction

The topic of enhancing and valorizing the cultural heritage has witnessed a growing interest in contemporary culture. Over the decades, a proper lighting design has become one of the main components of every public space project, due to the technical improvements in the lighting sector, as energy consumption and quality of emitted light, but also due to cultural and social phenomena [1]. Along with an increasing concern with outdoor lighting [2], urban refurbishment programs are progressively aiming to the enhancement of the identity of the cultural and architectural heritage of the cities, by actually designing and improving the light in public areas, as paths, squares or green areas, as well as on the exterior of monuments, sculptures, buildings and structures; consequently, cities have started to live more at nighttime. There are more people enjoying nightlife today, when compared with the early 90s, and lighting is one of the dominating forces for this particular shift: a well-lit path or a well-lit monument or landmark invites spectators to enjoy the city atmosphere, along with its cultural assets and their characteristics [3]. The design of the lighting for the cultural heritage is mainly focused on the enhancement of its historical-artistic characteristics and its perception in and along with the urban scenario. In order to have a good visual impact, it is necessary to use the light with extreme precision on selected elements, while avoiding luminous flux dispersion in other directions, and avoiding, as much as possible, the light pollution of the environment [4].

In [5], the authors report a lighting project for an old town in Italy, where many municipalities are undertaking the renovation of the public lighting system by substituting the existing luminaires with new ones equipped with Light Emitting Diode (LED) technologies, to increase the energy efficiency, reduce the maintenance costs, while improving the lighting performance. However, in the past, the luminaires replacement often involved the replacement of light sources with Correlated Color Temperature (CCT) equal to 2500 K with a low Color Rendering Index (CRI), typical of high-pressure sodium systems, with colder white light sources (CCT about 4000 K) with a higher CRI [6]. These refurbishment actions raise questions on the use of such high CCT light sources, in particular on the effect on the typical perception of architectures and urban landscapes. In order to overcome these criticalities, today it is possible to use LED sources with lower CCT, which are able to better simulate the perceptive effect of typical high-pressure sodium systems, while still improving color rendering and energy efficiency. In general, from the analysis of the current situation, it emerges that, in most cases, there still is a general lack of proper guidelines for the lighting design of monumental buildings, a fundamental step in the improvement of the perception and valorization quality of the cultural heritage and the touristic attractiveness of the sites [6]. In Cyprus, the valorization of the historic center of Paphos was realized by lighting the characteristic elements in two different ways [7]: the commemorative columns were lit from below with recessed LED light sources, while the commemorative busts were lit straight on, in order to light up the faces evenly. Instead, the lighting of walk paths has been addressed with diffuse or spot light sources. The spotlight approach has been reported in several projects, as in the lighting retrofit for the Parque Rodò [8] in Montevideo, Uruguay, or the Tree Library [9] in Milan, Italy. In both projects, the spotlight street lamps were used across the whole area, positioned in such a way as to create a sequence of lit and shadow areas, enhancing the suggestiveness of the main walk paths and main stationary areas. Instead, in the case of the lighting design for the Darsena [10] in Milan, Italy, diffuse light sources, installed below the eye-level, were used to evenly lit all the walk paths, both the main and the secondary ones.

In this work, the Parque del Retiro, a green area at the center of the city of Madrid, Spain, has been studied. In previous works [11], a survey has been carried out, in order to define the current conservation state of the Park and verify the use and valorization of the architectures and vegetation, through a rigorous methodological approach. As a second step, different lighting design proposals have been developed, in order to enhance the valorization and safety of the Park during the night. In particular, the lighting design focused on the enhancement of the Paseo de las Estatuas de Reyes, one of the main access paths of the Park, right next to the Puerta de España, the historic gate to the city. Through the use of DIALux evo lighting design software, it was possible to simulate and compare different design solutions, thus identifying the best solution able to guarantee, at the same time, adequate levels of illumination, an increasing of the feeling of safety in users and containing the energy consumption. Thanks to a multidisciplinary approach, the design proposal aims to enhancethe central main walk path, the entrance and the sidewalk paths, trying to attract more users into using the Park even at night.

2. The Parque del Retiro

The Parque del Retiro was built around 1630 to recreate in Madrid an area similar to the Palace of Versailles. The Park was commissioned by king Felipe IV as a recreational estate of the Kings of Austria; as the Borbón succession took place, the Park began to take the current appearance with its new architecture and vegetation. The research conducted previously by the authors [11] highlights the transformations that occurred through the centuries in what would later become one of the most important areas of Madrid.

The original project of the Park included a series of architectures around a Palace with its own garden: today what remains of the original building is called Casòn del Buen Retiro, while the garden has been through several transformations through the centuries. In 1620 the Estanque Grande was built, an artificial lake used as a water tank for both the Palace and the Park, later used also as a noble meeting

place in which playing and fishing. At the beginning of 1700, the Jardin del Parterre was designed following the stylistic dictates of the French Gardens, and new tree species and areas were added during the Borbón reign, also making the area accessible to the public in 1767. In the 19th century, the Parque del Retiro suffered considerable damage during the Independence War, but there are numerous historical tables that highlight the intense restoration work that took place in the aftermath, with the insertion of additional architectural elements. In the last years of the 19th century, the Park hosted several international exhibitions, which required the addition of a series of exhibition pavilions and green areas, such as the Palacio de Velazquez and the Palacio de Cristal, next to a splendid water jump, the Cascada, initially used for irrigation of the Park itself. In the first decades of the 20th century, the architect José Urioste y Velada and the architect Luis Bellido designed the new fence and the new entrance doors. During the 20th century, several commemorative monuments were built in the Park, as the one dedicated to king Alfonso XII, in the Estanque Grande, and the one dedicated to the historic gardener Cecilio Rodriguez. In recent years, the Bosque del Recuerdo has been added, following the terrorist attack in Madrid in 2004, to commemorate the 191 victims.

The Parque del Retiro is crossed by several walk paths which lead the visitors from the gates through the gardens. The Paseo de las Estatuas de Reyes is one of the main entrance avenues to the Park, and it is characterized by the presence of 13 marble statues of Spanish Royalty. During the Reign of Felipe V, the architects Juan Domingo Olivieri and Felipe de Castro were called to design the decoration of the upper balustrade of the main façade of the Royal Palace, which involved the placement of 114 statues. During the Reign of Carlo III, the statues were moved in order to chisel the name of each statue. However, they were not put back in place. Instead, the statues were relocated in different parts of the city, such as the Plaza de Oriente, the Jardines de Sabatini and in the Parque del Retiro. The Paseo de las Estatuas de Reyes is an avenue about 220 meters long and 20 meters wide, with a central geometric decoration made of short hedges. On the sides of the hedges, the thirteen statues of the kings and queens are placed on pedestals of the same height. The avenue is connected at one end with the Calle Alfonso XII by the Puerta de España, designed in 1893 by the architect José Urioste y Velada, and on the other end with the Estanque Grande, an artificial pond used by the Royalty to play and fish as well as serving as a water reservoir for the fountains.

3. The lighting design concept

Currently, there is no suitable lighting system for the night hours able to enhance the characteristic elements and guarantees a minimum level of safety of the Paseo de las Estatuas de Reyes. In order to obtain a lighting proposal that takes into account many aspects, particular attention is linked to the study of the Spanish legislation of 2006 published in Madrid [12]. It is a regulation for the correct design and installation of new lighting systems in public environments. Also, in the development of the different concepts, particular attention has been paid to the aspect of safety in Parks, which is one of the main factors to ensure the use of these places at night. During daylight hours, thanks to the great availability of natural light, the Park is the place where people establish relationships with other individuals, exercise or simply stay outdoors and enjoy the different species of fauna and flora of which it is composed. It is precisely this safety that is reduced at night by severely limiting the number of people who decide to spend time there, due to inadequate lighting systems. Adequately illuminating a green area does not, however, only guarantee high levels of illumination, but it is necessary to adapt the lighting to the various areas of the Park in order to create a bright environment capable of harmonizing lights and shadows, inducing safety in users, without harming the fauna [13,14]. The lighting project, proposed for the Paseo de las Estatuas de Reyes, which represents one of the fulcrums of the Parque del Retiro in Madrid, on the one hand seeks to highlight the characteristic aspects of the avenue, on the other hand to comply with the regulatory and energy saving requirements. Through a hierarchy of lights, the concept of the lighting projecttries to make visitors perceive the different importance of the Park areas; at each level of importance of an area of the Park corresponds different levels of illumination. Specifically, the areas of the Park under study were classified according to three levels of importance, which were

matched by three different levels of illumination. In opposition to the illuminated areas open to visitors, areas not accessible at night have been kept dark. In the development of the concept, the main avenue, consisting of hedges and statues throughout the walk, has been identified as the main area and therefore the highest levels of illumination have been provided for it. The second lighting level (lower than that used for the first level areas) is used for the entrance to the Park, while the third lighting level (the lowest) is used to illuminate some secondary walk paths and the boundaries of the Park.

The lighting of the main avenue has been designed to enhance the statues, which represent the historical and cultural value of the royal dynasties; each of them represents a royal member of the Spanish dynasty, from which the avenue itself takes its name. With regard to the entrance "Puerta de Espana", through which access to the "Paseo" is accessed, the lighting project has had two main objectives: (i) to ensure an adequate level of lighting that allows visitors to access the Paseo safely and (ii) to invite people to enter the Park. The two objectives were achieved by highlighting the stairs and the central door, with its stone columns of great architectural value. Thus designed, the lighting of the entrance also serves as a reference for those outside and inside the Park helping them to locate the entry and exit point, helping to increase the sense of safety in people. Finally, some of the secondary walk paths that start from Paseo, as well as the boundaries of the Park, have been considered at the third level of importance, to which correspond the lowest illumination levels. The lighting of the secondary walk paths aims to allow passage between the various areas of the Park, as well as to extend the area available to visitors. Furthermore, illuminating the boundaries of the Park, aims to increase the sense of security both in people inside and outside the Park. With this aim, the Paseo was lit through pole-mounted systems with direct light symmetric optic (iGuzzini Crown). In addition to pole-mounted luminaires, further luminaires (iGuzzini iPoint) were considered to better improve the visibility of the vegetation that mark the borders of the Paseo. Projectors (iGuzzini MaxiWoody) and luminaires for walkways (iGuzzini Walky) were used to light the Puerta de Espana and its stairs. Finally, pole-mounted systems with direct asymmetric optic were chosen for the secondary walk paths. All luminaires are manufactured by iGuzzini and are characterised by having the CCT equal to 3000K and CRI of 80 [15].

In order to optimize the energy consumption, the management of lighting fixtures has been designed according to two light scenarios. The two scenarios vary with different days of the week to take into account the different turnout at the Park:

- Scenario #1, in which all the luminaires are turned on according to the hierarchy above described (Figure 1);
- Scenario #2 where, assuming that few people use the Park, the luminaires used to lit the Paseo were dimmed, while those on the secondary walk paths were turned off. Conversely, the Puerta de España lighting was kept as Scenario #1 to attract visitors; the Park boundaries were also maintained lighted (Figure 2).

Table 1 lists the model of the luminaires, luminous intensity distribution, number of luminaires, luminous flux for a single luminaire and electric power for a single luminaire, upon varying the lighting scenario.

In order to compare and optimize different lighting design solutions, a detailed virtual model of the investigated part of the Park was built in the simulation software DIALux evo. In particular, much cure has been paid to the modelling of the Paseo de las Estatuas de Reyes and the Puerta de España. The secondary walk paths as well as the vegetation adjacent to the Paseo were also modelled. To ensure a virtual model as close as possible to the real one, the virtual model was created on the basis of a geometric survey of the Parque del Retiro. Without a photometric surface characterisation, the surfaces colour was deduced by using the photos taken during the previous survey of the Retiro Park [11]. **Figure 3** shows the virtual model of Park developed using the software DIALux evo.

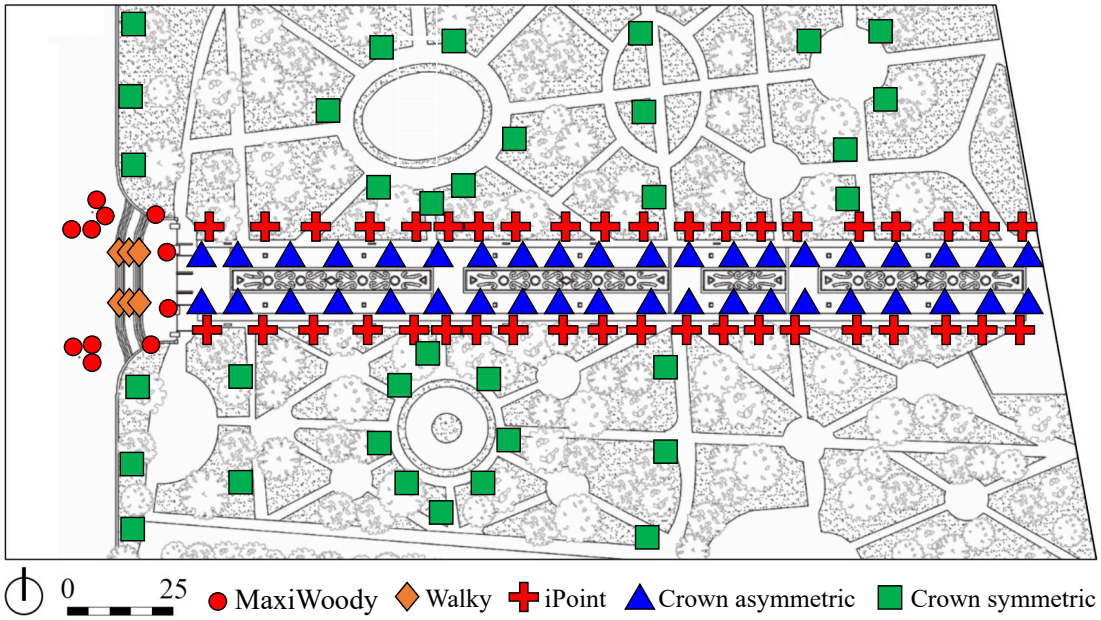


Figure 1. Layout of the luminaires for Scenario #1.

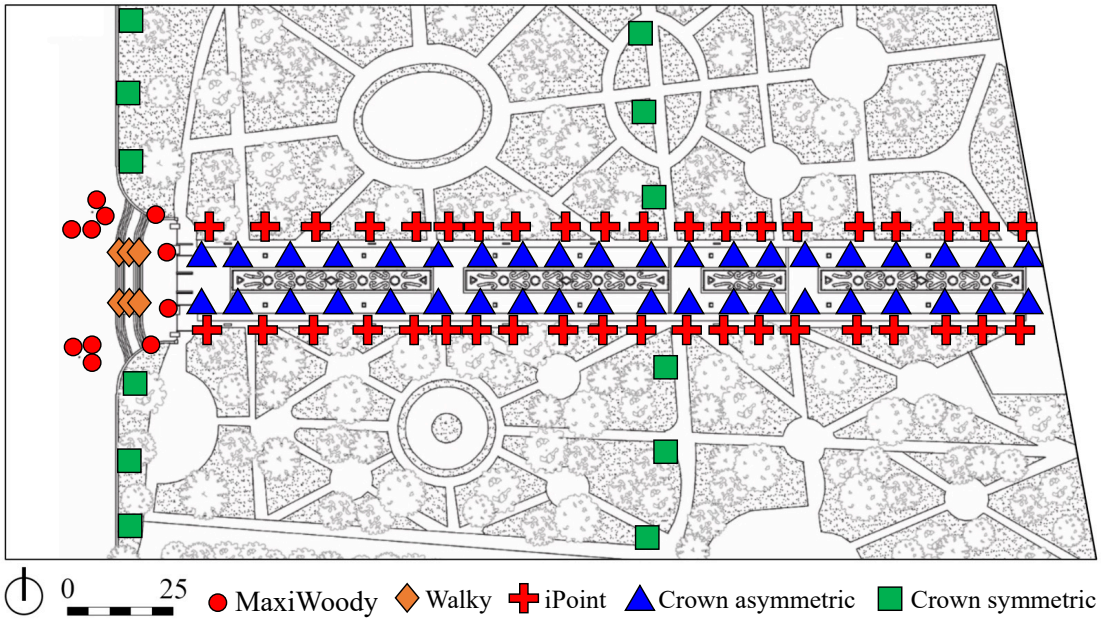
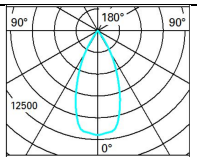
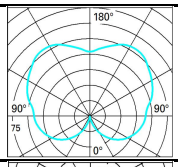
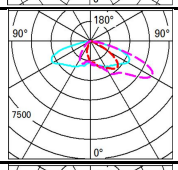
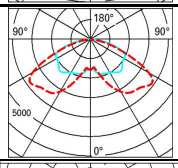
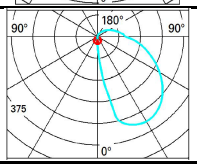


Figure 2. Layout of the luminaire for Scenario #2.

Table 1. Luminaires used in both scenarios based on manufacturer data [15].

		Scenario #1			Scenario #2		
Manufacture model	**Luminous intensity distribution**	**Number of luminaires (-)**	**Luminous flux for a single luminaire (lm)**	**Electric power for a single luminaire (W)**	**Number of luminaires (-)**	**Luminous flux for a single luminaire (lm)**	**Electric power for a single luminaire (W)**
BV05_LW72 MaxiWoody		1 6 1 4 4 2	8400 8000 7000 5500 3000 1000	52 49.5 43.3 34.0 18.6 6.2	1 6 1 4	8400 8000 7000 5500	52.0 49.5 43.3 34.0
E049_A15H iPoint: Pole		40	662	4.9	40	662	4.9
EH50_B22J Crown: Pole		1 17 15	8380 7000 6000	84.6 70.7 60.6	6 3 3	7000 3000 2000	70.7 30.3 20.2
EH55_B23J Crown: Pole		38	10530	100.5	38	4000	39.2
EI33.01_B30P Walky LED		3 5 4	250 200 150	1.7 1.3 1.0	3 5 4	250 200 150	1.7 1.3 1.0

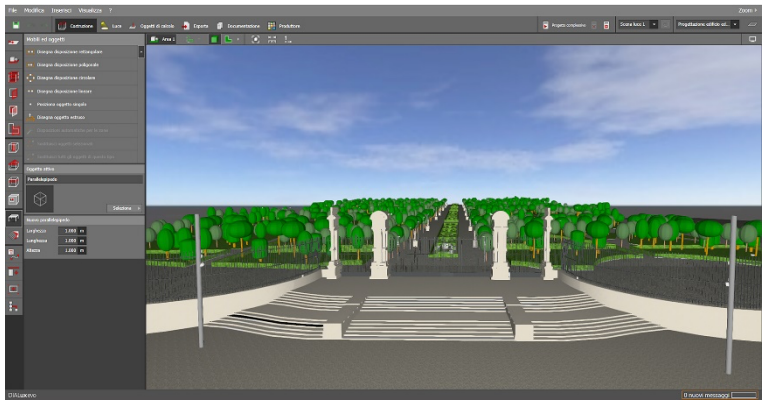


Figure 3. Parque del Retiro virtual model developed in DIALux evo.

In **Figure 4**, different views of the two designed scenarios are reported. In particular, **Figure 4**a and **Figure 4**b show a top view of Scenario #1 and Scenario #2, respectively. It can be noticed that in Scenario #2 (**Figure 4**b) luminaires to lit the secondary walk paths are turned off. Comparing **Figure 4**a and **Figure 4**b, the dimming effect on the luminaires installed on the Paseo can be seen.

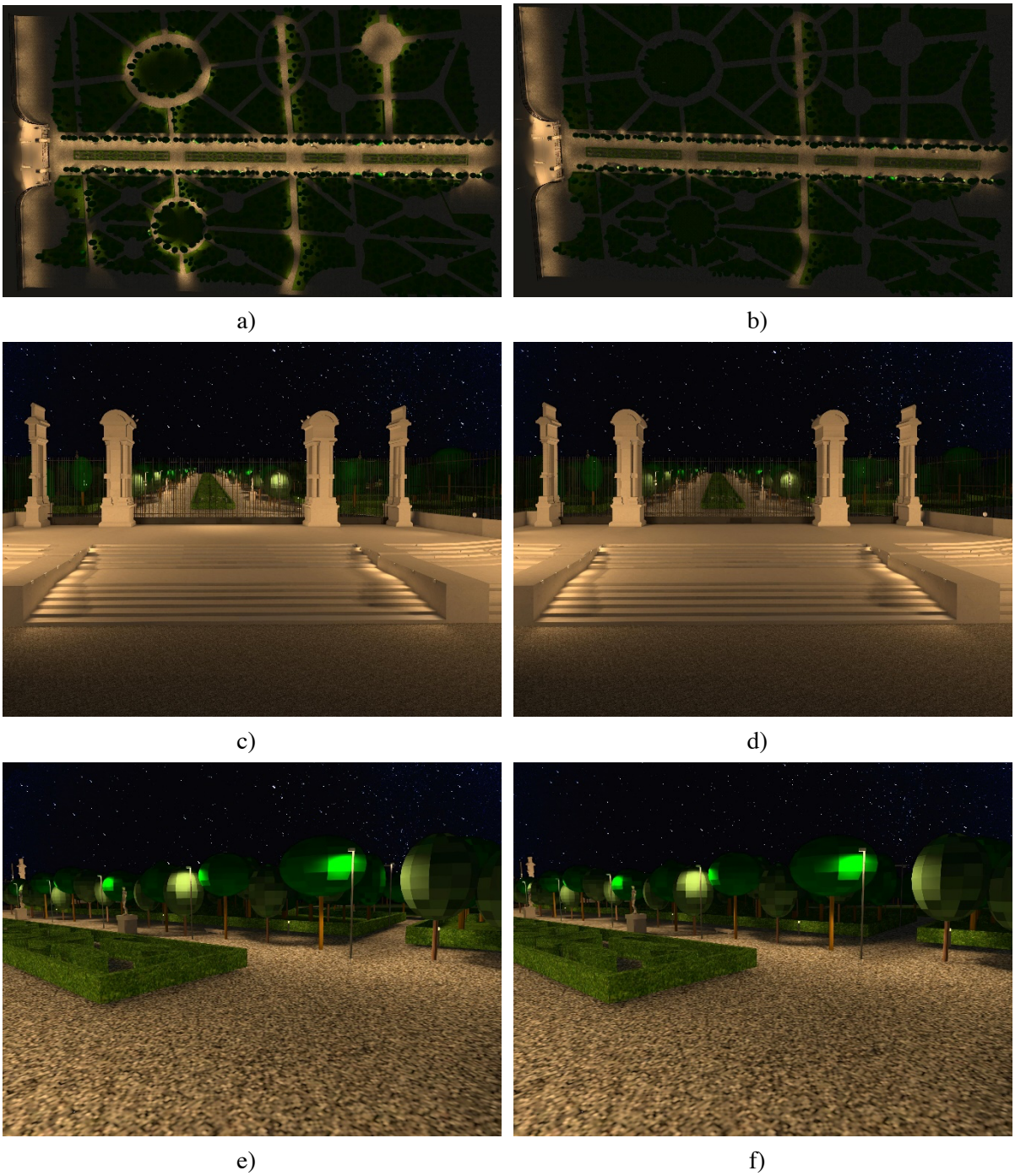


Figure 4. Images elaborated for the two scenarios using DIALux evo.

Figure 4c and **Figure 4**d exhibit a view of the Puerta de España for Scenario #1 and Scenario #2, respectively. As described above, both scenarios show the same lighting design solution. The projectors were installed at an average distance of about 4 meters to allow illuminating the entrance and stairs uniformly. In order to ensure the average illuminance and uniformity values recommended by standards, additional footpath luminaires were added on the stairs.

Finally, **Figure 4**e and **Figure 4**f display the internal view of the Park from the Paseo for the Scenario #1 and Scenario #2, respectively. These figures highlight the differences in space perception when users walk through the Paseo de las Estatuas de Reyes. In particular, the use of pole-mounted luminaires allows to light properly the statues and the Paseo. When the light comes from the top downwards, the sculptures are homogeneously illuminated and visitors can admire them in their entirety. In addition, in Scenario #2 (**Figure 4**f) the secondary walk paths are not lighted.

In order to calculate the yearly electric energy consumption for the different scenarios, an operation schedule has been hypothesized, as reported in **Table 2**.

Table 2. Summary of the yearly operation schedule.

Month	Park opening	Park closure	Sunrise	Sunset	Daily operating time
January	06:00	22:00	08:30	18:15	07:15
February	06:00	22:00	08:05	18:45	06:20
March	06:00	22:00	07:28	19:20	05:08
April	06:00	00:00	07:22	20:50	05:32
May	06:00	00:00	07:00	21:25	04:35
June	06:00	00:00	06:45	21:45	04:00
July	06:00	00:00	07:00	21:40	04:20
August	06:00	00:00	07:28	21:10	05:18
September	06:00	00:00	07:57	20:20	06:37
October	06:00	22:00	08:30	19:30	06:00
November	06:00	22:00	08:05	17:55	07:10
December	06:00	22:00	08:30	17:50	07:40

As it is possible to deduce from Table 2, the daily operation time has been hypothesized considering the opening and closing time, as well as the monthly sunrise and sunset hours, for a total of 2125 hours of operation time during the whole year: in particular, the artificial lighting system has been set to turn on 30 minutes before the park opening time until the sunrise, and from the sunset until 30 minutes after the park closing time.

Figure 5 reports the electric energy consumption associated to the combination of the two scenarios during the different days of the week (weekdays or weekends) across the whole year. In particular, considering as design parameters the lighting performances (uniformity, valorization of the cultural heritage and sense of safety) and electric energy consumption for both scenarios, the optimal combination was developed mixing the two parameters mentioned above: the lighting design expressed in Scenario #1 (all the luminaires turned on) has been used during the weekends' evenings (when the visitors' flow is usually higher) in order to maximize the visiting experience, while the lighting solution from Scenario #2 (dimmed luminaires in Paseo, luminaires turned off in secondary walk paths) has been used during the weekdays and the weekends' mornings, in order to minimize the electric energy consumption while still guaranteeing an acceptable level of lighting in the main areas.

Figure 5 highlights that:

- the yearly value of electric energy consumption calculated for the combined scenario (equal to 7780 kWh) is slightly higher than the value returned by a hypothetical continuous use of Scenario #2 alone (5961 kWh), while still being significantly lower than that associated to a hypothetical continuous use of Scenario #1 (14538 kWh);
- the yearly value of electric energy consumption associated to the weekends' evenings (Scenario #1 design solution) is only 0.8 times lower than that calculated during the weekdays and

weekends' mornings (Scenario #2 design solution), despite representing only the 26% of the total operation time;

- the yearly trend shows the positive effect in reducing the electric energy consumption associated to artificial lighting thanks to the switching between solar and legal time (27th of March and 30th of October).

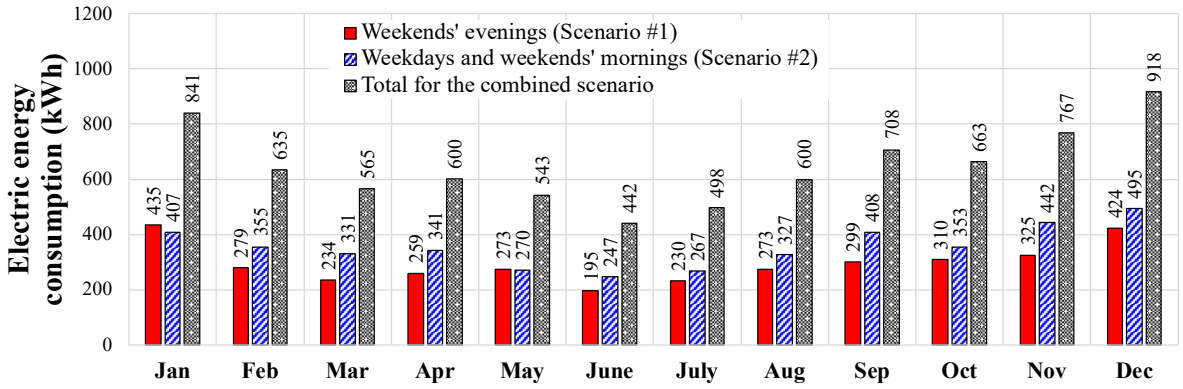


Figure 5. Summary of the electric energy consumption in the combined scenario.

4. Conclusions

In this research, the lighting design for the Parque del Retiro in Madrid, and in particular for one of its main gates and walk paths, Puerta de España and the Paseo de las Estatuas de Reyes, is discussed. Two different scenarios have been carried out in order to compare two different approaches in the lighting design: the first scenario aimed to emphasize the lighting uniformity, the valorization of the cultural heritage and the sense of safety, while the second scenario aimed at valorizing only the main areas of the Park while keeping low the electric energy consumption. Through the use of DIALux evo lighting design software, it was possible to simulate and compare the two different scenarios, thus identifying the best solution able to guarantee, at the same time, adequate levels of illumination, an increasing of the feeling of safety in users and containing the energy consumption. In order to do so, these two scenarios were then used in a weekly schedule, resulting in the design of a combined lighting system, able to maximize the valorization of the Park in the key days of the week, while keeping a lower energy consumption during the other days, still guaranteeing the enhancement of the key areas of the Parque del Retiro, the Puerta de España and the Paseo de las Estatuas de Reyes.

References

[1] K.P. Mansfield, "Architectural lighting design: A research review over 50 years." *Light. Res. Technol.*, vol. 50, pp. 80–97, 2018.
[2] W. Jankowski, "Lighting: Exteriors and Landscapes", editor: PBC International Inc., New York, 1993.
[3] M. Tural, C. Yener, "Lighting monuments: Reflections on outdoor lighting and environmental appraisal.", *Build. Environ.*, vol. 41, pp. 775–782, 2006.
[4] F. Falchi, R. Furgoni, T.A. Gallaway, N.A. Rybnikova, B.A. Portnov, K. Baugh, P. Cinzano, C.D. Elvidge, "Light pollution in USA and Europe: The good, the bad and the ugly.", *J. Environ. Manage.*, vol. 248, 2019.
[5] M. Beccali, M. Bonomolo, A. Galatioto, E. Pulvirenti, "Smart lighting in a historic context: a case study.", *Manag. Environ. Qual. An Int. J.*, vol. 28, pp. 282–298, 2017.
[6] L. Valetti, A. Pellegrino, C. Aghemo, "Cultural landscape: Towards the design of a nocturnal lightscape.", *J. Cult. Herit.*, vol. 42, pp. 181–190, 2020.
[7] iGuzzini, LDPi. DoubleN Electrical Consulting Engineers LLC, Dark Architectural Lighting, "La Riqualificazione Del Centro Storico Di Pafos", accessed on June 4, 2021.

[8] Disano illuminazione, "Parque Rodó, Montevideo", accessed on June 4, 2021.
[9] iGuzzini, Inside Outside - Petra Blaisse, Studio Giorgetta, "La Biblioteca Degli Alberi", accessed on June 4, 2021.
[10] iGuzzini, J.F. Bodin, E. Guazzoni, S. Rossi, P. Rizzatto, D'Appolonia S.P.A., Manens Intertecnica S.R.L., "La Darsena", accessed on June 4, 2021.
[11] D. Carleo, M. Gargiulo, L. Corniello, M. Scorpio, G. Ciampi, P. Chías Navarro, "Il Linguaggio Dell'architettura Funzionale e Della Memoria Nel Parco Del Retiro a Madrid/ The Language of Functional Architecture and Memory in the Retiro Park in Madrid", *Proceedings of the Connecting. Languages Distances Technologies. Proceedings of the 42th International Conference of Representation Disciplines Teachers*, 2021.
[12] Dirección General de Industria Energía y Minas, "Guía de Gestión Energética En El Alumbrado Público", Consejería de Economía, Empleo y Competitividad, 2006.
[13] R. Laffi, S. Sibilio, M. Scorpio, G. Ciampi, A. Rosato, Y. Spanodimitriou, "The lighting refurbishment of places of worship: The case study of the Church of "Santa Maria di Piedigrotta."" *Proc. Sci. Technol.*, vol. 2, pp. 102-112, 2019.
[14] M. Scorpio, R. Laffi, M. Masullo, G. Ciampi, A. Rosato, L. Maffei, S. Sibilio, "Virtual reality for smart urban lighting design: Review, applications and opportunities." *Energies*, vol 13, 2020.
[15] iGuzzini illuminazione S.p.A, "Outdoor Lighting", accessed on Apr 14, 2021.