Romanian Journal of Civil Engineering, Volume 17 (2026), Number 3

The socio-economic impact on a small city through the adoption of energy-efficient outdoor lighting solutions

Impactul socio-economic generat de implementarea soluțiilor de iluminat exterior eficiente energetic într-un oraș de mici demimensiuni

Anca Manolescu[1], Stănescu Ionuț[1]

[1]Technical University of Civil Engineering of Bucharest, Romania
66 Pache Protopopescu Boulevard, 021414 Bucharest, Romania
E-mail: anca.manolescu@utcb.ro, ionut-mihail.stanescu@phd.utcb.ro

DOI: 10.37789/rjce.2026.17.3.12

Abstract: *Urban areas consume over 65% of global energy, much of which is used for street and public lighting. As energy costs rise and the need to reduce CO_2 emissions grows, smart lighting emerges as a key strategy for energy conservation, safety, and urban aesthetics. Cities are adopting energy-efficient LEDs and smart systems with features like dimming and safety controls, allowing real-time, remote management of lighting based on area usage.*
Though implementing smart systems city-wide is costly, a gradual approach targeting specific areas can be effective. Lampposts equipped with connected lighting can provide additional services, such as public Wi-Fi and support for IoT sensor networks, which monitor environmental factors like air quality and waste management. Smart lighting can reduce energy consumption by 50-70% without compromising safety, enhancing the city's appeal and attracting visitors and investments.

Key words: reducing CO_2 emissions, energy efficiency, lamppost, smart lighting

1. Introduction

Outdoor lighting is crucial for equity and accessibility in urban areas, often taken for granted until it is absent. Poor lighting can lead to safety issues, deter public space use after dark, and exacerbate social inequality by neglecting less-lit areas, reducing community engagement, and increasing isolation. Cities invest significantly in lighting, which often uses outdated and inefficient technologies. Adopting energy-efficient solutions like LED and smart systems not only cuts costs and CO_2 emissions but also enhances public safety and the urban aesthetic. These initiatives also support economic development by enabling nightlife and improving community safety, potentially reducing crime rates by 20% and traffic accidents by 35%.

The article was received on 07.04.2026, accepted on 11.09.2026 and published on 22.09.2026

Public lighting uses a significant amount of global electricity and contributes notably to city energy costs and CO_2 emissions, prompting cities to pursue more sustainable solutions. Traditionally, high-pressure, and low-pressure sodium lamps have been prevalent due to their high luminous efficacy and lower initial costs but incur higher long-term costs and energy usage compared to modern LEDs. LED technology, despite higher upfront costs, offers longer lifespans, better energy efficiency, and lower total CO_2 emissions. As technology progresses, many cities are shifting towards LED lighting, which is expected to constitute 89% of global streetlights by 2027, though only a fraction will include smart features. Smart lighting systems, which integrate sensors and controls for more efficient operation, promise even greater energy savings and operational benefits. These solutions can be implemented through low-cost connectivity and have a massive impact on energy savings and maintenance costs. [2]

The additional energy savings of smart connected lighting compared to LED lighting are at least 60% higher, ensuring a sound return on investment. [1]

2. City model for smart public lighting projects

Many cities, including Chitila near Bucharest, are adopting smart public lighting systems to update the traditional, inefficient lighting network. Chitila's strategy involves modernizing its lighting infrastructure to enhance component performance and installing a remote management system for more efficient control of each lighting unit.

This modernization aims to reduce electricity consumption and cut CO_2 emissions by 20.82% from 2009 levels and achieve a 7% reduction in energy consumption by improving energy efficiency and incorporating renewable energy sources. This project is expected to create cleaner, safer, and more livable spaces for citizens.

In this context, the SEAP (Sustainable Energy Action Plan) outlines the following key actions/measures:

- Gradual implementation of the project - a pilot for remote intelligent control of public lighting, without compromising standardized lighting parameters (telemanagement and remote management of the system), by establishing the goal of achieving at least a 30% reduction in energy consumption as a performance indicator;
- Conducting a rigorous lighting audit of the city streets, classifying the streets into lighting classes according to international standards (SR EN 13201);
- Conducting a thorough economic and financial study regarding the direct or indirect management of public service;
- Replacing all existing lighting sources, such as mercury vapor lamps, with High Pressure Sodium Lamps or LED light sources;

- Implementing dimming (reducing the light output during certain time intervals and in specific areas, adjusted according to traffic and the safety conditions of the area);
- Expanding the lighting system by designing the installation in accordance with the energy performance and lighting standards applied in the European Union;
- Modernizing pedestrian lighting (sidewalks) by using fixtures equipped with energy-efficient light sources.

The public lighting system of the city of Chitila includes 1,484 lighting fixtures with power ratings ranging from 50 W to 250 W, structured as follows:

Table 1

List of Lighting Fixtures

	Lighting Fixture	Number of Units
1	SELUX 70 W Luxten	34
2	AstraRoad 150 W Lena Lighting	142
3	Eurostreet ET25 70 W General Electric	979
4	Eurostreet ET25 150 W General Electric	142
5	Eurostreet ET40 250 W General Electric	79
6	Decorative Indirect Post	14
7	Other 70 W	21
8	LED 50 W Electromax	24
9	LED 59 W Philips	10
10	LED 73 W Philips	23
11	LED 80 W Total Green	10
12	LED 50 W N/A	6
	TOTAL	1484

According to the inventory elements, the installed power of the street lighting is Pi = 159.049 kW.

Calculated electricity consumption assuming the lighting fixtures operate at 100% capacity is Wan = 699.815 MWh.

The distribution of lighting fixtures is shown in Fig. 1 and Fig. 2 illustrate the SIP lighting fixtures and distribution of installed power in Chitila by technology used.

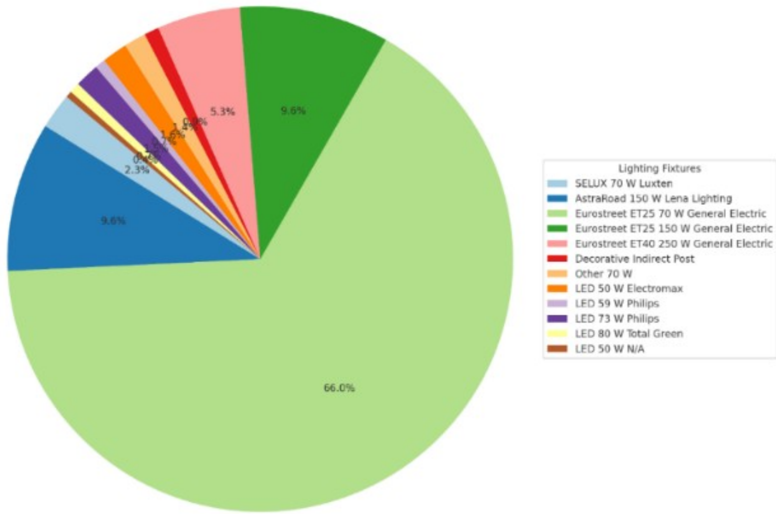

Fig. 1. Distribution of Lighting Fixtures

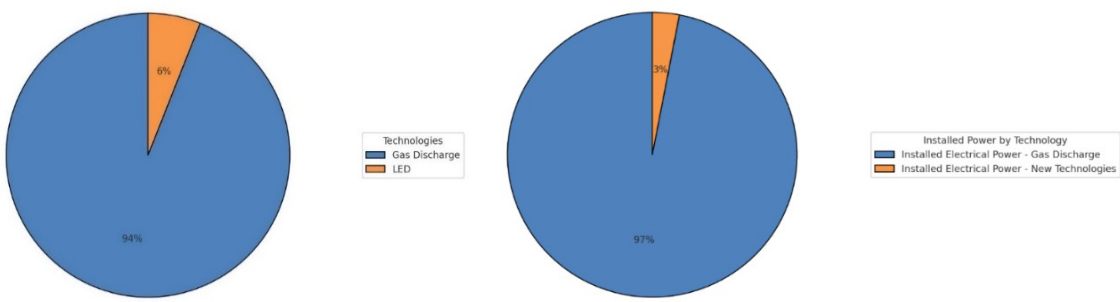

Fig. 2. SIP lighting fixtures and distribution of installed power in Chitila by technology used

The modernization and expansion of the public lighting system will assure certain public utility requirements and needs of the local community, as follows: improving the quality of public lighting in the City of Chitila, avoiding light pollution, optimizing energy consumption, ensuring continuous operation of public lighting, enhancing the level of civility, comfort, and quality of life, increasing the level of individual and collective security within local communities, as well as improving the safety of road and pedestrian traffic, supporting and encouraging the socio-economic development of localities, operating and utilizing the service infrastructure under conditions of safety, profitability, and economic efficiency and promoting the sustainable development of the public lighting system.

Technical Solution for the modernization and reintegration work for the Public Lighting System (SIP) includes the following investment objectives: construction of a new public lighting network, reintegration and modernization of the existing public lighting, provision of renewable energy sources (photovoltaic panels) and implementation of a remote management system for public lighting.

The investment comprises 2,018 lighting points, including the following components: 16,200 meters of new public lighting electrical network, 2,018 LED lighting fixtures, 452 poles, 18 public lighting distribution boxes, 14 switching points, 1,474 remote management control modules, 27 network parameter analyzers, 4 zonal control boxes for remote management, 1 remote management system workstation and 6 lighting systems equipped with photovoltaic panels. Lighting fixtures are equipped with high-power LED light source with color temperature Tc = max 4000 K and Color rendering index CRI ≥ 70.

The programmable electronic ballast is compatible with the type of light source used and it has the following functions: ensuring operation with a power factor >0.92 when operating at 100%, communication capability via DALI or 1-10V communication protocols and allows the reduction of luminous flux by at least 80% of the nominal flux value, in steps of at least 1%.

The lighting fixtures are equipped with a wireless individual control device (part of the control system) for independent command and control of the lighting fixture, using at least the 1-10 V or DALI communication protocols.

According to the Program on Increasing Energy Efficiency of Public Lighting Infrastructure, the remote management systems implemented in the project must meet the following minimum requirements:

- to install, commission/configure, and manage the lighting system at a low cost and without errors;
- to switch, dim, and increase the illumination levels according to ambient light, schedules, programming, calendars, or real-time signals;
- to collect and manage energy consumption data with high accuracy for the user; the system will generate automatic reports on annual consumption for the entire project;
- to identify faults, anomalies, and other malfunctions of the lighting fixtures and power supply;
- to monitor the operating hours and condition of lighting fixtures and electronic control devices for predictive maintenance purposes and to ensure warranty compliance; the system will generate an automatic report with the number of operating hours for each GPS-identified light point and an average of operating hours for the entire project;
- to collect data from light point controllers and provide it to the user or third-party software, such as Asset Management Systems (AMS) or Geographic Information Systems (GIS);
- to provide interfaces and/or mechanisms to interact with various sensors and smart platforms to adjust light levels and provide information that helps improve services, comfort, and safety;
- to be scalable to manage an increasing volume of data and a growing number of devices to accommodate future growth.

The remote management system will manage the entire network in the area and will have the capability for future expansion.

During the operation of the remote management system, continuous voltage will be maintained in the network, and the control of switching on/off/dimming of public lighting will be handled through modules installed on the lighting fixtures.

These modules will be independently addressable and will provide both local on/off control and real-time diagnostics of the lighting fixture.

In addition to information about the operation of the lighting fixtures, the remote management system will provide information about the power supply network, the quality of the electrical energy, as well as any potential faults or electricity thefts.

The management system interface is shown in Fig. 3:

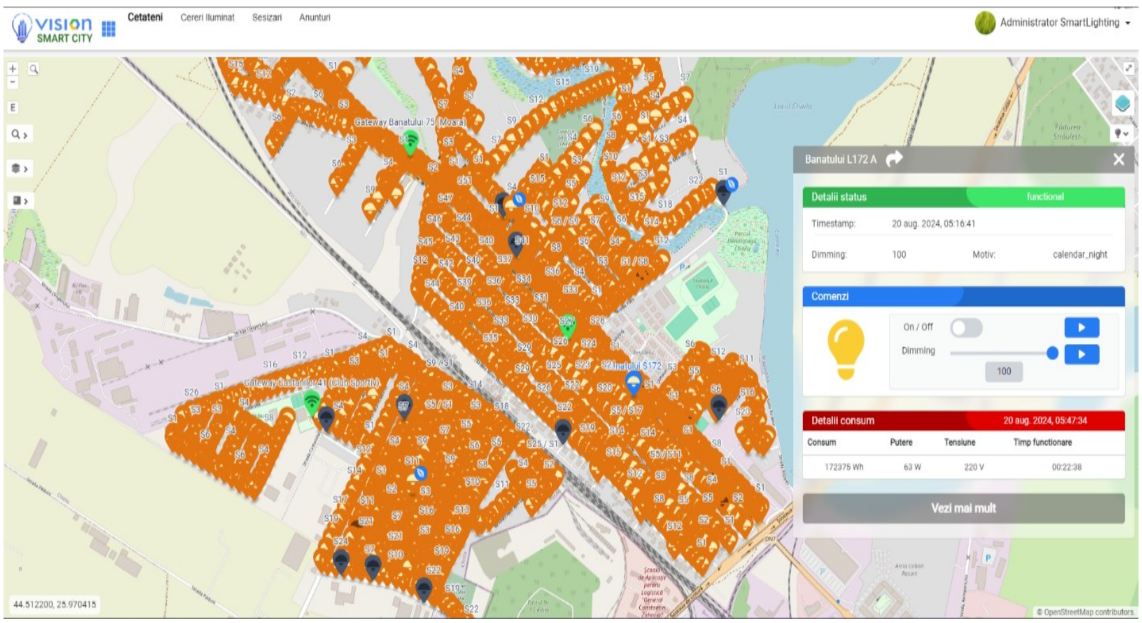

Fig. 3. Management system interface

Before starting the implementation of this project, the authorities developed a technical project that provided us with input data on key indicators such as total absorbed power indicator, total consumed energy indicator and carbon emissions indicator, crucial factors to improve in our project.

Total Absorbed Power Indicator

The newly installed lighting fixtures (CIL) are of the following types, centralized in Table 2:

Table 2

List of lighting fixtures and technical specifications

No.	Lighting Type	Technical specifications	Absorbed Power [W]	Number of Lighting fixtures	TOTAL Absorbed Power [W]
1	CIL 1	LED 10000 lm	62	372	23.064
2	CIL 2	LED 8600 lm	53	404	21.412
3	CIL 3	LED 7500 lm	45	489	22.005
4	CIL 4	LED 4500 lm	27.5	150	4.125
5	CIL 5	LED 3500 lm	21.5	38	0.817
6	CIL 6	LED 2000 lm	13.6	193	2.625
7	CIL 7	LED 8600 lm crossing system – 4 lanes	53	18	0.954
8	CIL 8	LED 8600 lm crossing system – 2 lanes	53	21	1.113
9	CIL 9	LED 13362 lm	77	279	21.483
10	CIL 10	LED 2730 lm pedestrian	24	37	0.888
11	CIL 11	LED 24744 lm	144	17	2.448

Total Consumed Energy Indicator

For the calculation of the annual electricity consumption indicator, we assume an operating time of 4,400 hours per year, mentioned in Table 3.

Table 3

Total consumed energy indicator

No.	TOTAL Absorbed Power [kW]	Annual operating time duration [h/year]	Estimated total annual energy consumption [kWh/year]
1	100.934	4400	401119.00

Carbon Emissions Indicator

For the calculation of this indicator, the information included in the "ELECTRICITY LABEL provided to non-household final customers who are beneficiaries of the universal service (at the universal service price) in the year 2021" is considered, with specific CO_2 emissions at the national level of 217.24 g/kWh.

Table 4

Carbon emissions indicator

No.	Estimated total annual energy consumption [kWh/year]	CO_2 emissions of the designed installation [t CO_2/year]
1	401119.00	87,139

Results within the project

Results obtained following the execution of the project for the reintegration and modernization of the public lighting system infrastructure in the City of Chitila.

Reduction in CO_2 emissions

- Indicator value at the start of project implementation:
  At the beginning of the project implementation, emissions were recorded at 312.438 tons of CO_2 per year.
- Indicator value at the end of project implementation:

At the end of the project implementation, the volume of greenhouse gas emissions resulting from public lighting in the study area is 89.550 tons of CO_2 per year.

This results in a reduction of greenhouse gas emissions (CO_2 equivalent) by 222.888 tons per year, which represents a minimum percentage reduction of 71.34% because of the project investments.

Reduction in annual primary energy consumption in public lighting (kWh/year)

- Indicator value at the start of project implementation:
  The annual primary energy consumption in public lighting is recorded at 1,044,943 kWh/year.
- Indicator value at the end of project implementation (output):

The annual primary energy consumption in public lighting is recorded at 401,119 kWh/year.

Thus, a reduction in primary energy consumption resulting from public lighting of 643,824 kWh/year is achieved, representing a 61.61% reduction because of the project investments.

Number of lighting fixtures installed, and number of light points controlled by the remote management system through the project:

- Indicator value at the start of project implementation: 0
- Indicator value at the end of project implementation (output): 2,018

A total of 2,018 LED lighting fixtures have been installed and are controlled by the remote management system.

Average illumination level (lx)

The indicators are calculated in accordance with the European standard SR-EN 13201:2015 for public lighting, based on the lighting audit report, resulting in the following values, centralized in Table 5:

Table 5

Average illumination level

Illumination level	Indicator value at the start of project implementation	Indicator value at the end of project implementation (output):
Average illumination level (lx) C1	2.7	33.77
Average illumination level (lx) C2	1.5	24.4
Average illumination level (lx) C3	1.0	18.8
Average illumination level (lx) C4	0.5	14.8
Average illumination level (lx) C5	0.1	9.1

Minimum maintained average luminance level (cd/m²)

The indicators from Table 6 are calculated in accordance with the European standard SR-EN 13201:2015 for public lighting, based on the lighting audit report, resulting in the following values:

Table 6

Minimum maintained average luminance level

Illumination level	Indicator value at the start of project implementation	Indicator value at the end of project implementation (output):
Minimum maintained average luminance level (cd/m²) for class M2	0.1025	1.77
Minimum maintained average luminance level (cd/m²) for class M3	0.247831	1.15
Minimum maintained average luminance level (cd/m²) for class M4	0.199516	0.88
Minimum maintained average luminance level (cd/m²) for class M5	0.096721	0.74
Minimum maintained average luminance level (cd/m²) for class M6	0.041811	0.48

Table 7 summarizes the indicators, and their respective values related to the project's goals of reducing CO_2 emissions, energy consumption, and improving public lighting quality, among other objectives.

Table 7

Indicators of the project

No.	Project Indicator	UM	Indicator Value at Project Start	Expected value at project end	Value Achieved During PT Design Phase	Final Value at Project Completion
1	Greenhouse gas emissions (CO_2)	t CO_2/year	312,438	130,069	87,139	89,550
	Reduction of CO_2 emissions	t CO_2/year	-	181,569	225,299	222,888
	Reduction of CO_2 emissions	%	-	58.11	72.11	71.34
2	Annual energy consumption	kWh/year	1,044,943	405,521	401,119	401,119
	Reduction in annual energy consumption	kWh/year	-	642,422	643,824	643,824
	Reduction in annual energy consumption	%	-	61.48	61.61	61.61
3	Length of the public lighting system	kWh/km	49,470	64,028	65,670	65,670
	Extension of electric network	km	-	15.6	16.882	16.882
4	Renewable energy sources	System	0	6	6	6
5	Number of LED lighting fixtures installed	Units	0	2,018	2,018	2,018
6	Number of light points controlled by the remote management system	Units	0	2,018	2,018	2,018
7	Number of poles installed by project	Units	1,531	1,983	1,983	1,983
	New poles installed	Units	-	452	452	452
8	Average illumination level	lx				
	Average illumination level (C1)	lx	2.7	30	31.2	33.7
	Average illumination level (C2)	lx	1.5	20	22.3	24.4
	Average illumination level (C3)	lx	1.0	15	17.3	18.8
	Average illumination level (C4)	lx	0.5	10	13.7	14.66

No.	Project Indicator	UM	Indicator Value at Project Start	Expected value at project end	Value Achieved During PT Design Phase	Final Value at Project Completion
	Average illumination level (C5)	lx	0.1	7.5	8.33	10.27
9	Minimum maintained average luminance level	cd/m²				
	Minimum maintained average luminance level (M2)	cd/m²	0.1025	1.5	1.56	1.77
	Minimum maintained average luminance level (M3)	cd/m²	0.2478	1	1.01	1.35
	Minimum maintained average luminance level (M4)	cd/m²	0.1995	0.75	0.78	1.07
	Minimum maintained average luminance level (M5)	cd/m²	0.0967	0.5	0.65	0.76
	Minimum maintained average luminance level (M6)	cd/m²	0.0418	0.3	0.42	0.55

The remote management (control) system includes all newly installed lighting fixtures in the designated areas, which are individually incorporated into the control system. This system's role is to monitor, intelligently manage, and remotely control the lighting fixtures, based on processing complex data algorithms from various sources and acquiring feedback information. The system was designed for prompt interventions in case of malfunctions and reducing costs associated with electricity consumption and maintenance of the public lighting system. The implementation of the control system was realized simultaneously with the installation of the lighting fixtures.

Below is the consumption variation graphs recorded following the completion of the project and after the implementation of the remote management system for the period March 1, 2024, to August 19, 2024.

The new smart public lighting infrastructure allows for the activation of presence detection from 9:00 PM to 9:00 AM, enabling the lights to dim as needed. When users are present, the lights dim to 60% power, and in their absence, they dim to 40%. Additionally, between 9:00 PM and 9:00 AM, the rain sensor ensures visibility during rain by only dimming the lights to 60% power.

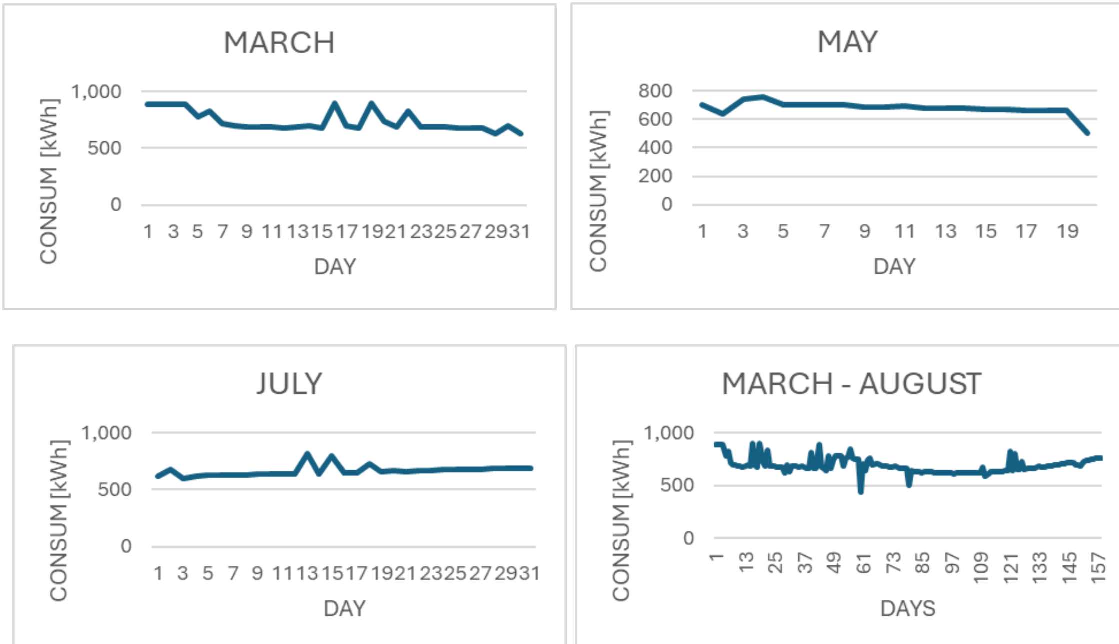

Fig. 4. Consumption variation graphs

The implementation of the project is alleviating the current negative social and economic impacts experienced by the city. It focuses on enhancing both the efficiency and effectiveness of the public lighting infrastructure, which in turn brings significant economic and social benefits.

Expected economic advantages are reduction in operating costs and lowering infrastructure operational costs.

The project aims to lower expenses associated with the maintenance and upkeep of the city's public lighting infrastructure. By implementing these efficient lighting solutions, the frequency and cost of repairs and replacements are expected to decrease, leading to substantial savings over time.

Using advanced lighting technologies and intelligent control systems, the project seeks to reduce the overall energy consumption of the city's lighting infrastructure. This will directly lead to lower electricity bills and a more sustainable budget for city operations.

Social benefits anticipated from the project are regarding improved public safety, enhanced traffic safety and also environmental benefits.

One of the primary social benefits is the increased security for residents after dark. Enhanced lighting in public areas helps reduce crime rates and the fear of crime, making residents feel safer when walking or commuting at night. This improvement in public safety has a direct and positive impact on the community's quality of life.

Better-lit streets and public areas contribute to a safer environment for both pedestrians and drivers. Improved visibility after dusk reduces the likelihood of accidents, thereby enhancing the overall safety of the urban environment.

The project will help in reducing various forms of pollution. By utilizing more efficient lighting options, light pollution is minimized, making the night sky more visible and reducing disturbances to wildlife. Additionally, lower energy consumption will lead to a reduction in CO_2 emissions and other harmful pollutants, contributing to a cleaner, healthier environment.

By focusing on these key areas, the project can create a more sustainable and economically efficient public lighting system and enhance the well-being and safety of the city's residents.

3. Conclusions

This study demonstrates the advantages of LED solutions in terms of energy efficiency, maintenance costs, and environmental impact. Although the initial costs for LEDs are higher, these are offset by long-term economic and environmental benefits. In contrast, sodium vapor solutions, while having a lower purchase cost, involve higher operating costs, greater CO_2 emissions, and a shorter lifetime.

Furthermore, integrating a remote management system into the LED infrastructure can further enhance efficiency by allowing precise control over lighting conditions. This system enables lights to be dimmed or brightened based on actual needs, optimizing energy consumption and extending the lifespan of the lighting fixtures. By reducing unnecessary energy use and improving maintenance efficiency, the remote management system helps in significantly lowering overall operating costs and environmental impact.

Smart connected lighting offers more lighting hours, but at reduced power levels, optimally adjusting to the immediate local needs and the preferences of citizens for specific locations and times.

The investment in this new infrastructure is significant and is most effective when implemented at least at the neighborhood street level. However, the energy-saving potential of smart connected lighting makes it a viable transition model, appealing to Energy Service Companies (ESCOs) and allowing cities with limited investment capabilities to achieve this transformation.

Compared to the smart, connected lighting, the lampposts could provide additional services, including offering a (potentially free) public Wi-Fi network, providing the powered foundations for a mesh network of (IoT) sensors across the city, helping drivers find a parking place, improving public safety, supporting environmental monitoring (air quality, waste, flooding, noise).

They could be a place for electronic street signage, public information and advertising (revenue), the home of sensors that helps to direct visually impaired people, a powered web of electric vehicles (cars, bikes) charging points, or even pedestrian-flow monitors that could help to keep the high street a vibrant place.[1]

The image of a city using such smart technology would also generally improve, attracting more visitors and investments.

References

[1] Colclough, G., Peeters, L, Protopapadaki, C., Borsboom, J. 2022. Smart lighting in cities. Factsheet.

[2] Pardo-Bosch, F., Blanc, A., Sese, E., Ezcurra, F., Pujadas, P. 2020. Sustainable strategy for the implementation of energy efficient smart public lighting in urban areas: case study in San Sebastian.

[3] Beaton, S., Lynch, M. 2020. WCCD – World council of city data. Societal Benefits of Improved Public Lighting.

[4] Econoler 2003. SUSTAINABLE STREET LIGHTING. Brighter cities, brighter future. THE ECONOLER SERIES. www.econoler.com

[5] Cellucci, L., Burattini, C., Drakou, D., Gugliermetti, F., Bisegna, F., Vollaro, A., Ferdinando, Salata, F., Iacopo Golasi, I. 2015. Urban Lighting Project for a Small Town: Comparing Citizens and Authority Benefits, 14230-14244; doi:10.3390/su71014230, ISSN 2071-1050. www.mdpi.com/journal/sustainability.