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RENEWING STREET LIGHTING WITH LED TECHNOLOGY: A SINGLE CASE STUDY IN CASARABONELA

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ABSTRACT

In 2015, the ecological, economic and social necessity of increasing energy efficiency contributed to street lighting renewal in the Spanish municipality of Casarabonela. Considering fixed operating and maintenance costs, it was a significant, long term investment with high impact for the community. Technicians chose LED light sources after studying technical and economic proposals submitted. Measurements of light levels, energy consumption and costs were carried out before and after the renovation. Once the chosen proposal was implemented, follow up surveys from technicians, maintenance workers and final users were collected. This case study aims to describe steps taken in the process of luminaires replacement. It has been estimated savings, expected and actual together with the return period on investment. This case may well serve as a prototype for a subsequent multiple case study which aims to validate a list of indicators obtained in a previous research.

Highlights:

- When valuing a luminaire, there may not be one that is the best in all parameters;
- Illuminance is not the only important indicator for final user satisfaction, correlated colour temperature and uniformity must be also considered;
- Indicators evaluated must be required in bids;
- Final savings can be greater than first estimated.

Keywords: LED lighting, municipalities, energy efficiency, indicator, street lighting, and sustainability

1. INTRODUCTION

Since the Spanish economic crisis started in 2007, public administrations in general and municipalities in particular have seen their budgets significantly reduced. Moreover, the progressive increase of energy costs and carbon footprint generated by energy consumption has forced local governments to study and optimize their consumption sources to comply with environmental objectives established by the European Union [1].

Between 2007 and 2010, the local government developed the Energy Optimization Plans (POE) with the objective of elaborating an inventory of every source of energy consumption in the municipality (public lighting, municipal buildings, etc.) as an indicator of residential activity, socio-economic factors, and even to estimate GDP and CO_2 emissions [2]. These plans also proposed specific measures to increase efficiency.

Conclusions of these plans most often showed the need to optimize and reduce consumption in public lighting installations. In 2009, Casarabonela power consumption percentage of street lighting compared with total electricity consumption was 47 %, almost half of the municipal electricity costs [3].

What's more, the recent development of new alternatives to traditional light sources LEDs, Micro LEDs, (Light Emitting Diodes much more efficient in theory) has also led municipal technicians to study a multitude of options that sometimes do not contain enough information or are not sufficiently detailed to be properly assessed. This new situation may create discrepancies about the proposals that are submitted to them, as to whether or not they will meet with the legislation and the specific needs of the municipality.

In 2015, a study was conducted by the authors of this paper [4] that aimed to identify a set of indicators whose assessment could help technicians in decision making. As Polzin et al indicated: "Municipal representatives often fail to evaluate the market for LED lighting" [5]. The study identified a series of indicators that could predict the suitability of a street lighting system. In order to verify their results, the authors will use this case study to initiate the validation in practice of their indicators.

In order to achieve this purpose, a single case study has been carried out in the municipality of Casarabonela. It has intended to check, considering the information collected, if decisions taken match with the result of indicator assessment.

2. BACKGROUND

Casarabonela is located geographically on the western edge of the Guadalhorce River Valley, south of the Ronda region, province of Malaga. It has been declared a Biosphere Reserve by UNESCO and classified as zone E1 according to CIE126–1997 [6]. 70 % of the municipality population resides in the city centre and the overall population has been slightly decreasing from 2009 to 2015 [7].

Provincial Government of Málaga elaborated Casarabonela Municipality's POE in 2009, Fig.1. This study, revised in 2012, showed the power consumption due to public lighting increased by almost 30 % in 2012 as compared to 2009. This power consumption represented 42 % of the total energy consumed and 36 % of the total electricity costs in the municipality.

POE conclusions reflected a "saving opportunity" [8]. Moreover, the new legislative requirements of the EU Regulation Commission Nº 245/2009 [9] prohibited the use of mercury lamps as of 2015. These two events forced the municipality to find alternatives to traditional lighting sources, a "more ecological and sustainable image of common outdoor areas" [10].

3. METHODS

A descriptive single case study [11] has been carried out to illustrate the whole renovation process. The data were collected in three stages.

The stage one is before the execution of the renewal actions:

- Update Casarabonela urban lighting inventory;
- Develop a renovation project and begin the contracting procedure of planned actions in the project;
- Examine the proposals presented for project execution;
- Measure of lighting levels in a sample of streets.

The second stage is after the execution of the renewal actions:

- Repeat lighting level measurements;
- Interview with municipal mayor, technicians and politicians;
- Interview with municipal maintenance staff;
- Interview with residents;
- Elaborate a comparative analysis of electric costs;
- Calculate the economic investment and the return period on investment (ROI).

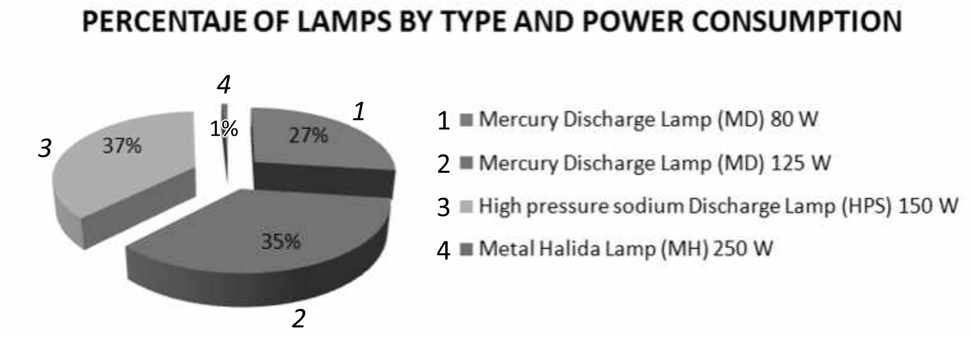


Fig. 1. Casarabonela urban lighting inventory (source: Casarabonela's POE)

Table 1. Casarabonela Inventory (Source: Provincial Government of Málaga)

Summary of required actions	Units
New Villa luminaire located in city centre streets and squares	365
New Fernandino LED module (LED Lamp + Gear Power) to install inside existing luminaires	40
Luminaire to install on a passage way ceiling	1
Cast aluminium bracket, of (0.6–0.7) m length	170
Cast column of 3.95 m high	71

Table 2. Bid Technical Requirements (Source: Provincial Government of Málaga)

Requirements	Values
Luminaire Material	Cast Aluminium
Luminaire Protecting Rate	IP65
Light Source	LED
Useful Life (Light Source)	≥ 90,000 h.
Heat dissipation elements in the light source	Yes
Light Source Luminous Flux	≥ 3,800 lumens
System Power (driver + light source)	≤ 38 W.
Correlated Colour Temperature	3,000 K (Warm White)
Upward light output ratio (ULOR)	≤ 1 %
Optic	Asymmetrical Distribution
Optical Unit Protection	IP54
Over Load Protection	Yes
Over Voltage Protection	≥ 10 KV.
Driver (Gear Power)	Electronic/Individual
Regulation	5 Steps Programmable Driver
Price	420 € (luminaire)/ 289 € (LED Module)

The third stage assesses presented proposals using the indicators.

4. DATA COLLECTED AND RESULTS

4.1. Updating of Casarabonela Urban Lighting Inventory

In November 2013, the public lighting inventory was updated by street and type of luminary to quantify the necessary technical and economical actions, Table 1.

Technicians also included the relocation or installation of new light points in areas that had shown a lack of quality of the lighting parameters during the inventory review. They increased the number of light points in some areas to increase the perception of safety and facilitate the use of public spaces for citizens [12]. Consequently energy consumption per capita increased in some areas [13, 14].

The diagnosis was completed with the inclusion of the renewal of three deteriorated electrical panels that didn't comply with the electrical safety current regulations [15].

4.2. Develop a Renovation Project and Begin the Contracting Procedure of Planned Actions in the Project

Technicians elaborated a project for the implementation of the inventory recommendations that finally amounted to 169,100 €. The contracting procedure was carried out by the City Council itself according to the state administrative regulations in force [16]. Several companies presented offers, of which only two completed the technical

Table 3. Comparative of Luminaires Offered

Mismatched Parameters *	BIDDER1	BIDDER2
System Power (driver + light source)	38 W	30 W
Luminaire Luminous Flux	3,328 lm	3,000 lm
Upward light Output Ratio (ULOR) (%)	< 1 %	0.74 %
Luminaire Efficiency	79 %	NP*
Luminaire Protecting Rate	IP44	IP65
Luminaire Price	420 €	386 €
Light Source Power	35 W	28 W
Led Module Luminous Flux	4,350 lm	4,000 lm
Colour Rendering Index	NP	>75
Led Module Working Current	500 mA	350 mA
Led Module Useful Life	68,000 hours	90,000 hours
LED Module Price	289 €	266 €

* *Not providing information, value, certification or required document*

and economic documentation required in the bid specifications.

The technical criteria for valuation of the offers included in the bid specifications are presented in Table 2.

The two final bidders were invited to install their luminaires as a test in several streets of the urban nucleus, as recommended by Polzin [5] with three purposes: to verify luminaires offered, to measure illumination levels provided by installed luminaires, and to follow up by assessing the degree of satisfaction for end users/residents.

4.3. Examine the Proposals Presented for Project Execution

An initial evaluation of submitted documentation by the bidders was carried out, according to the document "Technical requirements for luminaires with LED technology" of Energy, Tourism and Digital Agenda [17]. Subsequently, technical files and certificates provided were studied. Table 3 describes the parameters evaluated in which the bidders differed.

If bidder technical parameters are compared with technical requirements (Table 2), it can be deduced that Bidder 1 did not comply with "Luminaire Protecting Rate" nor "LED Module Useful Life" parameters. Both bidders failed to comply with "Correlated Colour Temperature" parameter, but municipal technicians accepted a value of 4,000 K.

4.4. Measurement of Lighting Levels in a Sample of Streets

A series of measurements were carried out on an example of five street roadways where the renovation was to take place.

The selected roadways were classified according to CIE and CEN / TR13201–1 "Road Lighting Part 1: Selection of Lighting Classes" [18] and UNE13201–2 "Road Lighting – Part 2: Performance Requirements" [19]; according to CIE126–1997 [6] all roads were classified as an E3 protection zone, because they were located in a residential area within the urban area, considered as a medium brightness or medium luminosity area, Table 4.

Measurements were always completed on the same streets and between the same luminaires. Identical inter-distances and measurement conditions were guaranteed at three different times:

1. The first series of measurements with the existing luminaires, before any action took place in the installation (in March 2014);
2. The second measurements with the test luminaires installed in the selected streets by the two final bidders (between March 2014 and January 2015);
3. A third series of measurements in the streets with Bidder 1's luminaires, replaced for Bidder 2's luminaires, which were ultimately selected by the municipality (during first semester of June 2015).

Table 4. Roadway Classification

Roadway Classification*	Type	Project Situation	Lighting Class	E_m, lx	E_{min}, lx
{1}Juan XXIII Avenue	D	D3-D4	S1	15.0–22.5	5
{2}Cantarraijana Street	E	E1	S2	10–15	3
{3}Saldaña Street	E	E1	S2	10–15	3
{4}Real Street	D	D3-D4	S1	15.0–22.5	5
{5}Francisco Herrera St.	D	D3-D4	S1	15.0–22.5	5

* *Real Decreto 1890/2008 [20]*

Measurements were obtained on windless nights without any other adverse weather conditions. The inter-distances chosen did not have any other light sources nearby (local, luminous signs, etc.) that might have interfered with measurements. Traffic was not cut off at any time, the technicians merely waited for the cars' light interference to disappear. A digital luxmeter, Grossen model Mavolux 50328 USB, provided a direct reading for each measurement.

The drawings are outlines of point grids selected by street, with measurements points, as well as the results of the mean and minimum illuminance and overall uniformity values obtained of each measurement carried out are presented in Table 5.

As the type of lamps is LEDs, a Maintenance Factor value of 0.85 can be considered for efficiency calculations [21]. This value corresponds to a cleaning interval of 3 years and a intermediate degree of contamination. The obtained results of the Road Energy Efficiency Class calculations, according Real Decreto 1890/2008 [20], showed a classification of "A" in all the streets.

4.5. Interview with Municipal Mayor, Technicians and Politicians

To get impressions about the whole process, the municipal technician who had witnessed the entire selection and renewal process, was interviewed. With regard to the bid selection, installation and subsequent start up period, he indicated that he had not detected any anomalies, difficulties or complaints. However, he did note that the selected luminaires were not of the highest quality although in his opinion they were technically sufficient. In addition, the mayor was interviewed and noted the opinions of his technicians and as well as of neighbours.

4.6. Interview with Municipal Maintenance Staff

One of the two municipal electricians was interviewed. He has been employed in the City Council for 20 years and was responsible for trouble shooting any incidents that occur in the daily operation of street lighting installation. The interviewee offered his experience and impressions about this particular case. During the selection phase, the electrician did not indicate anything worthy of mention.

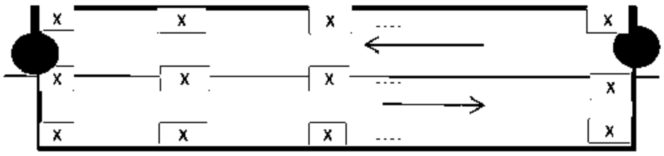
During the execution phase, he remembered that at first the neighbours protested, perceiving a lack of adequate lighting that made their walks less pleasant [22]. One of the motives for the complaints was that the front of buildings were not lit, however, none of these initial complaints lasted over time. There was also another incident, the driver deprogramming of all luminaires belonging to one circuit, which the manufacturer solved satisfactorily. He also indicated that currently, during the maintenance and warranty phase, he did not carry out any preventive or maintenance activities; he only attended to occasional incidents.

During the last months of the test period the installation suffered several problems: some drivers in one of the circuits failed due to over voltage failures in power line and some luminary screws fell out and several luminaires had to be repaired.

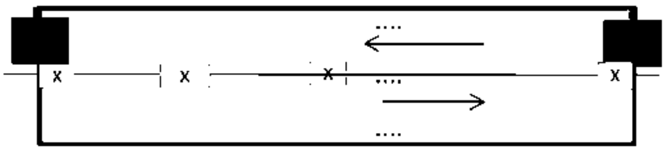
The awardees, as agreed, were collaborating and were going to analyze the damaged equipment. In addition, the company was checking for possible alterations or defects in power supply lines. These small repairs incurred expenses of approximately 600 € to the municipality.

The town electrician stated that the whole process of substitution, from the beginning to the present, was on the whole adequate, but he did con-

Table 5. Road Drawn Measurements and Results



{1} Luminaire layout	Measure Number	Light Source	Power, W	Bidder	Dates	Em, lx	Emin, lx	Uo
Heigh: 4m	1° (39)	MD	80		mar-14	6.6	2.9	0.4
Road width: 5 m.	2ª (66)	LED	30	2	jan-15	14.5	5.0 ↑	0.3 ↓
Interdistance: 24 m.	-	-	-	-	-	-	-	-



Luminaire layout	Measure Number	Light Source	Power, W	Bidder	Dates	Em, lx	Emin, lx	Uo
{2} Heigh: 3m	1° (12)	MD	80		mar-14	8.8	5.3	0.6
Road width: 2 m.	2° (11)	LED	30	2	jan-15	60.8	35.0 ↑	0.5 ↓
Interdistance: 17 m.	-	-	-	-	-	-	-	-
{3} Heigh: 3m	1° (15)	MD	125		mar-14	3.9	1.8	0.5
Road width: 3 m.	2° (15)	LED	30	2	jan-15	45.2	20.0 ↑	0.4 ↓
Interdistance: 19 m.	-	-	-	-	-	-	-	-
{4} Heigh: 3m	1° (12)	MD	80		mar-14	4.7	1.2	0.3
Road width: 3 m.	2° (12)	LED	38	1	jan-15	25.5	8.3	0.3
Interdistance: 19 m.	3° (17)	LED	30	2	jun-15	30.4	3.9 ↑	0.1 ↓
{5} Heigh: 3m	1° (11)	MD	80		mar-14	4.2	0.9	0.2
Road width: 3 m.	2° (11)	LED	38	1	jan-15	27.4	12.0	0.4
Interdistance: 21 m.	3° (17)	LED	30	2	jun-15	31.6	8.0 ↑	0.3 ↑

sider that some narrow streets were less illuminated, or had significant shadows.

4.7. Interview with Residents

Based on a small sample, residents living in the municipality have not been excessively positive regarding the renovation. They have noticed a change in the colour of the light, but they could not be sure if the perceived illumination had resulted in a higher quality. Although there were no specific complaints in historic centre, some neighbours did perceive a lack of lighting in residential areas when walking. They described totally dark areas between lamp posts. During the interview, when indicated that luminary renovation process had resulted in an electric bill saving, interviewed neighbours understood that the action was justified, but would have preferred that the lighting conditions had not diminished in some areas.

4.8. Elaborate a Comparative Analysis of Electric Costs

A comparative study of municipal electric consumption in public lighting supplies was carried out to check if there was any saving during last 12-month period (July-2015 to June 2016) since the renovation in relation to electric consumption study carried out in 2012, Table 6.

According to obtained values, the annual energy saving (154,709 kWh) represented a saving percentage of 50 %, equivalent to 62t CO_2 equivalent, while economic savings, represented 48 % of annual costs.

4.9. Calculate the Economic Investment and Period of Return on Investment (ROI)

The amount to be used exclusively for the replacement of luminaires of total renovation budget was of 110, 460 €.

Table 6. Comparative Consumptions 2012–2015

Consumption and Costs Differences	Results
Number of Electrical Panel Studied	4
Costs 2012, €	46,027
Costs 2015, €	23,817
Difference, €	- 22,210
Power Consumption 2012, kWh	310,931
Power Consumption 2015, kWh	156,222
Difference, kWh	-154,709

Table 7. Return on Investment Period and Energy Consumption Cost Calculations

Cost Calculations	Results
Initial Investment, €	110,460
Maintenance Costs, €/2015	600
Reduction of Energy Consumption Costs, €/2015	22,210
Total Reduction, €/year	21,610
Return of Investment, years	5

Table 8. Light Evaluation Indicators and Associated Parameters

Indicator	Associated parameters	
Luminaire Design	Photometry Protecting Rate Mechanical Impact Protecting Code	Luminaire Efficiency Over Voltage Over Load Protection
Light Source Power	LED Module Power LED Module Working Current	LED Module Luminous Flux Useful Life
Spectral distribution of light source	Minimum wavelength [6] Correlated Colour Temperature	Colour Rendering Index
Regulation possibility		
Luminaire Cost		

With prices and technical characteristics of awardees' luminaire, a preliminary study of the period of return on investment was carried out and the results showed a return on investment period between 6 and 7 years. Taking into account that the warranty usually covers the first 5 years of installation [1] this theoretical return on investment period is too high, Table 7.

From later tariff study, it was observed that the renovation produced a significant real saving (around 50 %) of the energy consumption and public lighting supply costs in its first year. The reason was the efficiency of existing luminaries was very small compared to the luminaires installed. With the real data of consumptions, the return on investment period reduced at least 1–2 years. If real savings obtained in the first year were maintained, it would greatly increase the investment profitability.

4.10. Assess Presented Proposals Using the Indicators

The conclusions of the study carried out by the authors in 2015 [4] were used as selection of a luminaire indicators list [23] that could help municipal technicians in decision making about street lighting renewal.

A total of 5 luminaire indicators were obtained. However, once contrasted in practice, an additional parameter was found to be necessary such as the cost of the light source. This new indicator allowed us to elaborate the cost calculations and periods of return on investment.

A review of these results was carried out in two ways. First, by associating some parameters to each luminaire indicator, the authors were able to quantify indicators such as "Design of the Luminaire." This indicator also includes parameters such as efficiency, degree of protection against external elements, IP or IK grade. Second, the authors eliminated any indicators that were common to all proposals as they would not influence the results, for example "Road Classification", "Operation Hours" and "Extent of Illuminated Areas", Table 8. At the same time, any indicators, which value could only be obtained after installation, were also not considered [24].

The valuation was carried out once the indicators were associated with quantitative parameters, because the qualitative nature of some of them could distort their assessment. Qualitative assessment will transform quantitative data in results [25].

The luminaire parameter values provided by only the two final bidders were used. In order to as-

Table 9. Bidder Scores

VALUATION	BID TECHNICAL REQUREMENTS	BIDDER1		BIDDER2	
		VALUE	SCORE	VALUE	SCORE
1. Luminaire Design					
Photometry	Asymmetric	Asymmetric		Asymmetric	
Protecting Rate (IP)	IP65	IP44		IP65	A
Mechanical Impact Protecting Code (IK)	-	-		-	
Luminaire Efficiency,%	-	79 %	A	-	
Over Voltage/Over Load Protection, kV	10	Have it		Have it	
2. Light Source Power					
LED Module Power, W	38	38		30	A
LED Module Working Current, mA	-	500		350	A
LED Module Luminous Flux, lm	3,800	4,350	A	4,000	
Useful Life, hours	90,000	68,000		90,000	A
3. Spectral distribution of light source					
Minimum wavelength, μ	-	-		-	
Correlated Colour Temperature, K	3,000	4,000		4,000	
Colour Rendering Index	-	-		>75	A
4. Regulation possibility	5 Steps	Have it		Have it	
5. Luminaire/Led Module Costs, €	420/289 €	420/289 €		386/266 €	A

Notes: Don't provide information. A: Advantage over the other bidder.

sign to each one the score corresponding to the indicator, the parameters on which one was superior to the other were reflected as ADVANTAGE, (A). In case of a tie, none obtained ADVANTAGE, (A). The Table 9 shows obtained values.

5. DISCUSSION

Without a doubt, data collection has been complex given the diverse areas considered to obtain a complete picture of actions carried out in the municipality. There have been economic, technical as well as social implications.

Economically, it might seem that the price of the luminaire was the main indicator that City Council technicians ultimately used to make a decision, although it should be noted that only the bidders who justified the technical requirements were considered viable by the technical assessment. In relation to the economic results, the offer presented by Bidder 2 was the most beneficial for the City Council. This offer resulted in a real return on investment of 5 years, the same or less than the warranty period, considering the first year of the installation.

Clearly luminaire price and technical requirements compliance were the decisive factors in the final decision of the municipal technicians. It can be construed that the municipal technicians based their decision on the similar indicators because of the 15 technical specifications of the Bid, 8 of them coincided with the indicators evaluated.

Technically, both bidders provided practically all the technical documentation required, with the exception of the Mechanical Impact Protecting Code of luminaires and certificates of some UNE standards. In addition, to complying with the Bidding Technical Requirements, Bidder 2 provided the most complete and detailed technical information. Several luminaire parameters presented by Bidder 2 were also superior (for example, "LED Module Working Current" value, "Luminaire Protection Rate", and "Useful Life of Light Source").

The two bidders met energy efficiency parameters, obtaining both the Class A. However, the average illuminance levels measured for the selected roadways exceeded the established illumination levels (S1 or S2) by more than 50 %. Bidder 2's results did show one exception (Juan XXIII Avenue). In addition, there is a sample where the road average illuminance level is five times higher than the pre-existing levels (Cantarraijana Street) measured on that street.

The results obtained, regarding minimum illuminance levels, are slightly better in Bidder 1 in relation to Bidder 2 and both meet the established levels, except Bidder 2 in one street. Regarding overall uniformity levels, both proposals showed worse or equal results in all streets except one where both improved (Francisco Herrera Street). Illumination levels measurements would have been carried out systematically according to UNE-13201–3 [26]. However, this case has not considered them.

Maintenance staff interviewed indicated that they were satisfied, as they were not required to perform periodic maintenance. But the street lighting installation had suffered mechanical breakdowns and failures in luminaires that should not have occurred during the first year of operation. The town electrician was also satisfied with the response that the Bidder had given to these failures, although the municipality had to make payments during the first year guarantee.

Socially, an overview of neighbours' opinions showed that initially their complaints were due to a feeling of lack of uniformity in some residential areas near the historic centre. Despite increasing illuminace levels, measurements also confirmed the existence of new shadow zones like "bright and dark patches" [27]. This assessment contrasted with the fact that some of the new luminaires had been installed to eliminate poorly lit areas. The new luminaire, installed in the same places as the previous installation, in most cases, generated new shadow zones as corroborated by Valentová and Quicheron's study [28].

Although the measurement results showed an increase of illuminance levels in all the roads studied and an improvement of minimum illuminance levels in the majority of them, these changes were not uniform and people interviewed did not identify any significant improvements in the daily use that they made of the street lighting installation, In addition, light source colour temperatures were not measured, as light spectral characteristics may have an impact in the design and appearance of public lightings [29] and colour difference may modify people's opinion [30]. The bid technical requirements only included a parameter related to the spectral distribution of the light source, the "Correlated Colour Temperature". As a result, the bidders have not provided enough information, so this indicator probably wasn't evaluated satisfactorily.

Using a list of indicators preselected in a previous study, the assessment of two bidders has been done in a straight forward way. One bid has result advantageous over the other in one parameter without taking into account the degree of improvement that this difference in value contributed to the luminaire. In consequence, every parameter defined by the indicator had the same weight. As there were only two bidders with one luminaire each, this difference in value has not been relevant.

The result of the evaluation of the indicators coincided with the decision made by the municipal technicians and validated 53 % of the indicators. Indicators list assess technical and economic aspects, but they do not assess residents' opinions of installation once renewed. Residents' opinions without a doubt have effectively detected a lack of uniformity and this need to be considered before the final project implementation. Clearly a small sample installation allows for a more complete overview of the renewal project before carrying out the full execution.

6. CONCLUSION AND POLICY IMPLICATIONS

The objective of this case study has been to evaluate the actions carried out in 2015 to replace street lighting installation in municipality of Casarabonela. At the same time, the authors have revised the conclusions of an earlier study with the aim of using the indicators selected in that study. The goal has been to verify if the municipal technicians would have chosen the same offered luminaire if they had used these new indicators.

Results indicated that the best bidder in technical characteristics, luminaire lower price and LED Module lower power value, is the one that got the best score in the indicator assessment and coincided with the option chosen by technicians. On the other hand, the bidder who obtained better results in the light levels measurement, failed to obtain the contract, mainly due to the price of the luminaire and some technical parameters in which the bid was overcome by the opponent. Clearly when assessing a proposal, all parameters play a role and there may not be one bidder who is best in all areas.

Street lighting execution project met the technical requirements. The levels of illuminance increased but the overall luminance uniformity worsened. Annual savings of 48 % (22,210 €/year) and a decrease of 50 % (62t CO_2 equivalent) in CO_2 emissions per year were finally obtained with a Return of Investment of 5 years.

This case study has also been used to justify the addition and elimination of some indicators from a previous study. The parameter assignment to the indicators allowed for a better assessment procedure to quantify qualitative indicators. The luminaire price indicator has been added, as an essential parameter in the valuation of the contracts signed by Public Administration.

Although results indicated proposed indicators are correct, a uniformity indicator would be include. More cases that contain a greater number of bidders and type of luminaires would corroborate or refute the conclusions obtained, and demonstrate the convenience of weighing the evaluation parameters or indicators.

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