2

ENERGETIC EFFICIENCY

2.1 INTRODUCTION

2.1.1 Governments and efficient use of energy

Governments are increasingly aware of the need for efficient use of energy and the high potential for savings that can be obtained. For this reason, have set the objective of reducing consumption in the short term and offer aid to implement measures that promote the efficiency. This is intended to achieve the objective proposed in a given period of time.

According to the European Commission, in the breakdown of the cost of electricity of European Councils, one of the most significant is the lighting which can be up to 60% of the cost. In addition, the European Union has been set to reduce by 20% the consumption in electric energy to the exterior lighting of the 2020 [1].

The majority of measures are aimed mainly to the use of technologies such as lighting in solid state (Solid State Lighting – SSL), which is based on (LED) light-emitting diodes and has high savings, greater durability and low maintenance. There are also additional measures based on power on-off control systems to maximize the efficiency of the elements belonging to the lighting set [1].

These lighting management systems are programmed to make lights turn on and turn off at the right time. There are different types and among them some are more efficient than others:

- *Analog clock*: consists of a simple program which shows on time and the shutoff.
- *Photovoltaic cell:* measures the brightness level and when it reaches a minimum orders to turn on the lights.
- *Astronomical clock:* consists of a system with a database that calculates the output and the sunset every day of the year for each area, normally with a forecast of about ten years [2].

2.2 CARBON PRINT

The carbon footprint is the totality of effect greenhouse (GHG) emitted by direct or indirect effect of an individual, organization, event or product. This is measured in mass of CO_2 equivalent [3].

The reduction of the carbon footprint is important because greenhouse gases are diminished, since these are the main triggers of climate change, which has a progressive effect and consistent over our planet. Therefore, it should be noted the importance of taking measures of prevention, reduction or compensation [4].
Energy efficiency helps to achieve this objective, since performing a reduction in consumption also produces a reduction in emissions. Therefore, it is interesting to be aware of the amount of energy consumed, what measures can be developed to make a consumption as efficient as possible and thus try to reduce polluting gas emissions to mitigate the effects that may have on the atmosphere.

2.3 OBJETIVE

An alternative to the current complementary off exterior lighting & lamps ignition management system has been developed in this project and we have used the Twilights (civil or nautical) instead of sunset and sunrise. Must be taken into account that the Twilights are periods of time in which, despite the fact that the Sun has still not come out or already has been, there is still sunlight.
The difference between sunrise and sunset and the Twilights resides at the height of the Sun with respect to the horizon in the rise and sunset height is 0°; While in the twilight, depending on which it is deemed, the height is-6° for the civil or -12° to the nautical.
The proposed method is based on astronomical calculations for the exact position of the Sun in the sky in a place determined by its coordinates (latitude and longitude) for each day of the year. With these calculations is obtained, for each day, the exact time of the sunrise and sunset and, with this, you can calculate the moments in which occur the twilight to set as start and end time that the lighting has to be on.
With the use of the twilight instead of the rising and setting of the Sun Gets a reduction of the time that the lights need to be fired. This way, achieves energy savings and a reduction in pollution.

2.4 METHOD USED

In order not to lengthen this article will make reference to which I had the opportunity to write in 2016 entitled: INCIDENCE OF HEIGHT SOLAR ANGLE TO DETERMINATE TIMES TO SWITCH ON/OFF THE LIGHTS posted at this Congress

2.4.1 Calculation with excel

To make the calculations described above two books Excel have been in what is simply need to enter the following parameters:

- Latitude and longitude
- Date and time.

The first book contains solar calculations and is second all the towns and cities of Spain. When you select one of them, later is written the name of a municipality belonging to the province, writes the desired date and with this information sheet generates a report with the calculated results and the graphs corresponding to the time of output and sunset, the hours of the Twilights, duration of day and night, etc.

Calculating the savings for spain

To perform this calculation, you need to know the annual energy consumption in Spain, which according to the IDAE, for 2017, is estimated to be of 5296 GWh. Therefore the first step is to know the daily consumption of energy.

$$5296\ \frac{\text{GWh}}{\text{year}} \times \frac{1\ \text{year}}{365\ days} \times \frac{1.10^6\ \text{kWh}}{1\ \text{GWh}} = 14\ 509\ 589'\ 04\ \frac{\text{kWh}}{\text{day}}$$

The next step is to find the hours of darkness that exist for each day. Since the hours of darkness a day vary according to the season of the year (in winter more hours of darkness and less summer). The day has more hours of darkness is 21 December coinciding with the winter solstice. As an example, has decided to choose a municipality at random, in this case Alconera (Badajoz) and extrapolate the data obtained in this town to all Spain.

The first step to calculate the savings in Spain is to use the spreadsheet to find out the average of the night hours per day in three cases: sunrise – sunset, civil twilights and nautical twilights. To calculate this average, it is used the summer solstice (December 21st), the shortest night of the year; and the winter solstice (June 21st), the longest night.

Dark summer (21st June) Solstice hours = 9'321 h (Fig. 2.1)

DÍA	21	HORA	0	Zona GMT	Dif. Horaria [HZ]	Día (h)
MES	6	MINUTO	0	0	0	14,67875922
AÑO	2017	SEGUNDO	0	0 h 25,91'	0,431792073	14h 40,7'
	(°) grad	(') min	('') seg	(°) grad	Signo Hemisf.	Noche
Latitud				38,3964686	1	9,321240776
Longitud				-6,4768811		9h 19,3'

Fig. 2.1 Data from the hours of light and darkness take account of sunrise and sunset in Alconera (Badajoz) from Excel sheet 21/06/2017

Hours (21 December) Winter Solstice darkness = 14'679 h (Fig. 2.2).

Now, the same step is performed to calculate the hours of darkness taking into account the Civil Twilight.

DÍA	21	HORA	0	Zona GMT	Dif. Horaria [HZ	Día (h)
MES	12	MINUTO	0	0	0	9,321176112
AÑO	2017	SEGUNDO	0	0 h 25,91'	0,431792073	9h 19,3'
	(°) grad	(') min	('') seg	(°) grad	Signo Hemisf.	Noche
Latitud				38,3964686	1	14,67882389
Longitud				-6,4768811		14h 40,7'

Fig. 2.2 Data from the hours of light and darkness take account of sunrise and sunset in Alconera (Badajoz) from Excel sheet 21/12/2017

Hours darkness taking into account the Civil Twilight on the Solstice of summer (June 21) $= 24 - (20'41162947 - 4'509450283) = 8'098$ h (Fig. 2.3).

DÍA	21	HORA	0	Zona GMT	Dif. Horaria [HZ]	Civil
MES	6	MINUTO	0	0	0	4,509450283
AÑO	2017	SEGUNDO	0	0 h 25,91'	0,431792073	4h 30,6' UTC
	(°) grad	(') min	('') seg	(°) grad	Signo Hemisf.	Civil
Latitud				38,3964686	1	20,41162947
Longitud				-6,4768811		20h 24,7' UTC

Fig. 2.3 Data from the Civil Twilight in Alconera (Badajoz) 21/06/2017 extruded sheet Excel

Hours darkness taking into account the Civil Twilight on the Solstice of winter (December 21) $= 24 - (17'63508986 - 7'158942237) = 13'524$ (Fig. 2.4).

DÍA	21	HORA	0	Zona GMT	Dif. Horaria [HZ]	Civil
MES	12	MINUTO	0	0	0	7,158942237
AÑO	2017	SEGUNDO	0	0 h 25,91'	0,431792073	7h 9,5' UTC
	(°) grad	(') min	('') seg	(°) grad	Signo Hemisf.	Civil
Latitud				38,3964686	1	17,63508986
Longitud				-6,4768811		17h 38,1' UTC

Fig. 2.4 Data from the Civil Twilight in Alconera (Badajoz) 21/12/2017 extruded sheet Excel

And the same process is performed to the nautical twilight.
Hours darkness taking into account the nautical twilight on the Solstice of summer (June 21) $= 24 - (21'07688639 - 3'844193367) = 6'767$ (Fig. 2.5).

DÍA	21	HORA	0	Zona GMT	Dif. Horaria [HZ]	Náutico
MES	6	MINUTO	0	0	0	3,844193367
AÑO	2017	SEGUNDO	0	0 h 25,91'	0,431792073	3h 50,7' UTC
	(°) grad	(') min	('') seg	(°) grad	Signo Hemisf.	Náutico
Latitud				38,3964686	1	21,07688639
Longitud				-6,4768811		21h 4,6' UTC

Fig. 2.5 Data from the Nautical Twilight in Alconera (Badajoz) 21/06/2017 extruded sheet Excel

Hours darkness taking into account the nautical twilight on the Solstice of winter (December 21) $= 24 - (18'18919417 - 6'604837927) = 12'416$ (Fig. 2.6).

DÍA	21	HORA	0	Zona GMT	Dif. Horaria [HZ]	Náutico
MES	12	MINUTO	0	0	0	6,604837927
AÑO	2017	SEGUNDO	0	0 h 25,91'	0,431792073	6h 36,3' UTC
	(°) grad	(') min	('') seg	(°) grad	Signo Hemisf.	Náutico
Latitud				38,3964686	1	18,18919417
Longitud				-6,4768811		18h 11,4' UTC

Fig. 2.6 Data from the nautical twilight in Alconera (Badajoz) 21/12/2017 extruded sheet Excel

With these data, we proceed to calculate the saving energy, economic and CO_2 emissions that would occur using the civil and nautical twilight instead of the rising and setting sun.

Saving half for the Civil Twilight calculation

To perform this calculation, is the difference between the hours of darkness average taking into account output and sunset and darkness hours average taking into account the Civil Twilight.

The Middle saved time = (average hours dark) – (average hours darkness at civil twilight) = 12 – 10'811 = 1'189 h saved the day.

He is calculated now the percentage of time half saved the day with respect to the hours of darkness taking into account the sunset and the sunrise.

% saved time $= \frac{1'189}{12} \times 100 = 9'91\% \cong 10\%$

Now apply this percentage to the amount of kWh a day consumed in Spain.

Energy saving = 9' 91% 14 509 589' 04 kWh = 1 437 900'274 kWh per day.

To calculate the cost savings daily average has been used the data of the fixed price of the kWh in March 2017, which is 0' 12925 €/kWh [7].

Cost savings = 1 437 900'274 kWh × 0'12925€/kWh = 185 848'61€ per day.

Finally, calculate savings daily average of CO_2 emissions using the mix of the peninsular electric network of the 2016 has been estimated at 0'308 kg of CO_2/kWh [8].

CO_2 saved $= 1\,437\,900'274 \text{ kWh} \times \frac{0'308 \text{ kg } CO_2}{\text{kWh}} = 442\,873'844 \text{ kg } CO_2$ per day.

Calculation saving means to the nautical twilight

Also, some information about the number of streetlights and their average power is needed. For Spain, this information is obtained from the IDAE (Institute for Diversification and Energy Saving).

To perform this calculation, is the difference between the hours of darkness average taking into account output and sunset and darkness hours average taking into account the nautical twilight.

The Middle saved time = (average hours dark) – (average hours darkness at nautical twilight) = 12 - 9'592 = 2'408 h saved the day.

He is calculated now the percentage of time half saved the day with respect to the hours of darkness taking into account the sunset and the sunrise.

He is calculated now the percentage of time half saved the day with respect to the hours of darkness taking into account the sunset and the sunrise.

% time saved = (2´408)/12 × 100 = 20' 01% ≅ 20%

Now apply this percentage to the amount of kWh a day consumed in Spain.

Energy saving = 20' 01% 14 509 589 ' 04 kWh = 2 903 368'77 kWh per day.

To calculate the cost savings daily average has been used the data of the fixed price of the kWh in March 2017, which is 0' €12925/kWh [7].

Cost savings = 2 903 368'77 kWh × 0'12925€/kWh = 375 260'41€ per day.
Finally, calculate savings daily average of CO_2 emissions using the mix of the peninsular electric network of the 2016 has been estimated at 0'308 kg of CO_2/kWh [4].
Saving CO_2 = 2 903 368'77 kWh × (0´308 CO_2 kg)/kWh = 894 237'81 kg CO_2 per day.
Note: not all kWh consumed per day in Spain come from non-renewable energy, therefore, CO_2 emissions are slightly less than the calculated as in the peninsular power supply mix renewable energies are not taken into account.

2.5 TOOLS TO DEVELOP THE PROPOSED IDEA

To develop the idea previously developed a system of management of power and off the lighting based on the twilight, the following will be needed:

a) **Raspberry Pi**, (Fig. 2.7) is a computer very cheap and small dimensions (8'5 x 5'3 cm) which has an SD card reader, USB, Wifi, and Bluetooth ports among other things. Power will be used a mobile connection charger micro USB [1].

Fig. 2.7 Raspberry PI

On this computer the operating system that you want only to be loaded is necessary to load it onto the SD card and insert it into the reader. For this project any operating system compatible with Microsoft Excel, can load the worksheet is in this format. This computer will be in charge of calculating hours power-lighting for a given date and latitude and length.
Also you can add a series of sensors to improve their capabilities. Some sensors that could improve this system would be the real time clock or the light sensor. The latter is really interesting because you can strengthen the functioning of the proposed system, i.e., a brightness value is set (similar, or even a little less, than the of the light intensity of the Twilights taken as reference in a day) cleared) and if it decreases below this value, lights light up or remain lit. This is very useful for cloudy days or pollution episodes.

b) **Arduino** (Fig. 2.8) is an open source platform whose principles are having easy-to-use hardware and software [2] hardware, namely a plate Arduino-based software to automate the orders of Raspberry IP will be used for this project.

Fig. 2.8 Arduino UNO

Therefore, this automaton is responsible for performing the power-the lighting.

2.6 SIMILAR SYSTEMS IN THE MARKET

Currently in the market, there are many different options related to management systems of turning on and off the lighting. Some of them are:

Analog switch (Fig. 2.9): is an electromechanical device that turns on and off the lighting at a preset time. It is a very simple system but not so efficient because, as time goes by, some disarrangements happens. This means that some delays or advances will occur over the time that lights should to turn on or off [9].

Fig. 2.9 Analog switch

Twilight switch (Fig. 2.10): is an electronic device that has a photovoltaic cell. This cell compares the environmental luminosity with a preset value and based on this comparison, it turns on or off the lighting [9].

Fig. 2.10 Twilight switch

These switches has a delay system that helps its correct operation in order to eliminate possible failures caused by transient weather phenomena, car lights, etc. [9].

They also have some inconveniences like they are installed in hard access places, so, their maintenance or reparations are difficult to make. Additionally, a slow darken of the surface happens as time goes by, as a result of the pollution. This causes a loss of effectiveness and operations are not made in the required moments [9].

Astronomical switch (Fig. 2.11): this device has a special program that follows the timetable of the sunrise and the sunset of a specific geographic area just by putting the latitude and the longitude. Depending on the model, reprogramming can be done on a weekly basis up to 10 years after. They also have the possibility of advance or delay the timetables uniformly. This type of switches must have a good time base and a proper adjustment of the precision, if not, the system could be losing effectiveness over time [9].

Fig. 2.11 Astronomical switch

If the three types of switches are compared, the first one would be discarded because it is the least efficient. So, with the two remain switches, the astronomical one has a higher precision than the twilight switch because this last device has to deal with the effect of the pollution. The main effect of the pollution is continuous darken of the surface as dust deposits on it producing a precision disarrangement as time goes by.

That is why astronomical switches are more precise, because they do not rely on any external device that could be affected by environmental factors and therefore, disarrangements do not happened very often. In fact, they only depend on a good database.

In the next figure (Fig. 2.12), there is a comparative among the time that lighting is on with a twilight switch and an astronomical switch. With the twilight device can be observed as lighting time increases over years [10].

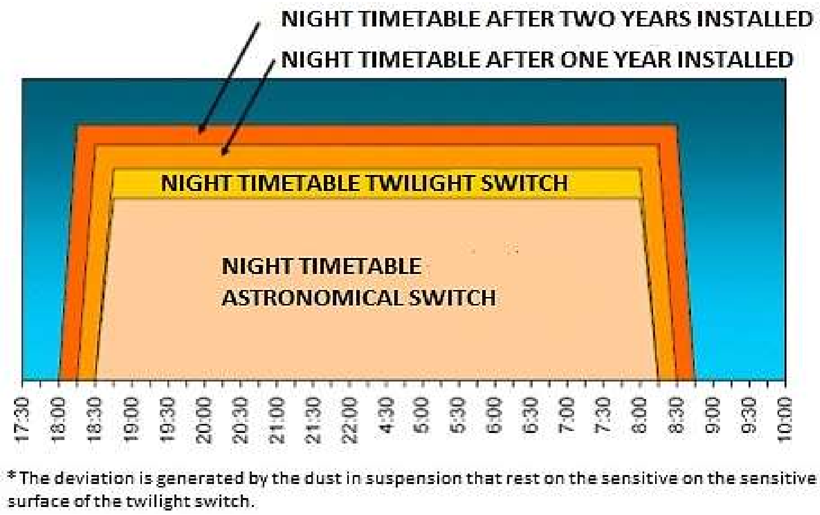

Fig. 2.12 Example of the crepuscular deviation in relation to the astronomical switch

2.7 COMPARISON BETWEEN MARKET SYSTEMS AND THE DEVELOPED SYSTEM

As it can be observed in the previous part, the most efficient device is the astronomical switch, therefore, is the chosen one to do a comparison with the system that is developed in this article. So, the similarities and differences are going to be analyzed.

The similarities between both systems are:

- Both conform to any part of the world by entering the geographic coordinates.
- They do exact calculations of the sunrise and the sunset for a specific place.
- Some astronomical switches have centralized management systems that can make online adjustments of the parameters, like in the developed system.

And the differences are:

- The astronomical switches have a database that contain all the necessary information to calculate the sunrise and the sunset and can last without reprogramming up to 10 years; meanwhile, the developed system do daily calculations, so, it does not need to be reprogrammed.
- The astronomical switches need a specialized technician to do the maintenance and the reparations; meanwhile in the proposed system any technician with computer knowledge can do it.
- In case of becoming obsolete, the astronomical switches are not reusable, while the developed system is, because all the parts have a multiple applications (together or separately) and the obsolete parts can be updated without change the entire device. In addition, this system can incorporate a multitude of accessories, so, with a few simple adjustments it can perform various functions.
- In case of damage, the replacements of the astronomical switch will be more expensive or could not exist, making the only option the change of the whole device; in opposition, with the proposed system, the replacements will be

cheaper and easier to find, so it will not be necessary changing the entire dispositive.

- Relative to the price, the astronomical switch costs approximately 230€; meanwhile the developed system has a Raspberrry Pi that costs 35€, an Arduino board whose price is 35€, a SD card that costs 20€ and an accessories kit that worths 30€ (all the prices are approximate). So, the entire set has a value of 120€ approximately. As it is seen, there is a huge price difference between both systems.

CONCLUSIONS

The management system of power-lighting based on the twilight is interesting since, with him, there is a saving energy, economic and pollutant emissions are reduced to the atmosphere.

While the savings produced is not very large (between 10-20%) for a complementary system is not a negligible amount. It, is intended to adjust the times in which it is necessary that the lights are on and thus make an efficient energy consumption.

To achieve maximum efficiency and savings, it would be advisable to combine this system with a LED light system to drastically reduce the amount of energy consumed.

In Europe, the approximate cost in public lighting is about 6.000 millions of Euros and the corresponding part for Spain is 1.000 millions. This evidence a problem because Spain is one of the European countries that has more daylight hours and, therefore, there is a need to solve this situation.

The management system to turning on and off the lighting based on the twilights is a quite interesting option because it produces an energetic and economic savings as well as a decrease of the polluting emissions to the atmosphere. With this system, it is intended to have an accurate timing of the turning on of the lighting and thus make an efficient energy consumption.

The saving of this system is among a 10% and a 20% (depending on the twilight that has been used). It is important to take into account that is a complementary system and that is why this percentages are so interesting.

To achieve greater efficiency and savings, it is recommended to combine this complementary system with a LED system to have a large decrease in energy consumption.

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ENERGETIC EFFICIENCY

Abstract: Currently, one of the main goals to achieve is the optimization of the use of energy to reach the highest energetic and economical savings. Therefore, regulations are focused on promoting and including policies that help to accomplish this aim progressively. However, most of them are mainly based on the use of LEDs and other similar elements.
This project has developed a managing method to turn on and off the lighting based on the twilights (civil and nautical) instead of the current methods, which are based on the sunrise and the sunset or in the luminosity variations. So, the developed method calculates the exact position of the Sun every day of the year and it provides the time of turning on and off with a higher accuracy. In comparison with current methods, it also produces energetic and economical savings.

Key words: solar calculations, energetic savings, rise and set calculations, twilight calculations, energetic efficiency

EFEKTYWNOŚĆ ENERGETYCZNA

Streszczenie: Obecnie jednym z głównych celów do osiągnięcia jest optymalizacja zużycia energii w celu osiągnięcia najwyższych oszczędności energetycznych i ekonomicznych. W związku z tym regulacje koncentrują się na promowaniu i uwzględnianiu polityk, które pomagają stopniowo osiągać ten cel. Jednak większość z nich opiera się głównie na zastosowaniu diod LED i innych podobnych elementów. W tym projekcie opracowano metodę zarządzania włączaniem i wyłączaniem oświetlenia w oparciu o zmierzch (cywilny i morski) zamiast obecnych metod, które są oparte na wschodzie i zachodzie słońca lub zmianach jasności. Tak więc opracowana metoda oblicza dokładną pozycję Słońca każdego dnia w roku i zapewnia czas włączenia i wyłączenia z większą dokładnością. W porównaniu z obecnymi metodami zapewnia także oszczędności energetyczne i ekonomiczne.

Słowa kluczowe: obliczenia słoneczne, oszczędności energetyczne, obliczenia wschodu i zachodu, obliczenia zmierzchu, wydajność energetyczna

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