Large usage of smart streetlights

Fabrizio Lovisetti

ABSTRACT

Public illumination causes high energy consumption, but light is not always used in the most efficient way. Lamps are always during working period, and intensity is at its maximum because it is not possible to modulate it.
Some types of streetlight, so called "smart", are slowly spreading in some cities, and they aim to solve these issues related to energy demand, increasing the efficiency of systems. In this article, an analysis is carried out of the potential of these solutions, what are advantages in environmental terms and what are the economical aspects of these systems.

Introduction

Electricity for lighting accounts for almost 20% of electricity consumption and 6% of CO_2 emissions worldwide[1]. This energy is almost all used for public illumination in cities. Hence, improving streetlight systems can be an efficient way to cut down energy demand and, in the end, a non-negligible fraction of CO_2 emissions. Streetlights often use energy in an inefficient way, because lamps are always on even when it is not necessary. Also, streetlights usually cannot work in an intermediate dimmed regime.

A first attempt to decrease this huge energy demand is replacing old lamps with most efficient LED ones. This can bring to save roughly 50% of energy, but some light is wasted anyway.

In parallel with this process, it is possible to install some control units in each streetlight to dim the light according to the surrounding conditions. This allows us to use only the necessary amount of light, which has a huge impact on the energy demand. These new systems are called "smart streetlights". These systems are still object of study, despite the technology needed to build them is mature. But there are already some examples of implementation in some cities, and several commercial products.

Smart street light solutions

The core idea of a smart streetlight is to have a dimmable lamp (LEDs are more suitable) that is connected to a control unit. Light intensity is modulated according to the external conditions. Several sensors are connected to the control unit, which provide information about the surrounding area. For example, the simpler sensor used is a light sensor (a photodiode or a photoresistor). Luminosity is adjusted according to natural light, avoiding running lamps at maximum power when sunlight is faint, but not absent.

Other sensors are proximity motion sensors (usually PIR or Passive InfraRed motion sensors). These sensors are able to detect pedestrians, bicycles and cars. Streetlights increase intensity when a person or a vehicle is detected in the street, and some seconds after the light is dimmed. Usually lights are not totally shut down due to security issues, but at least a 10-20% of the maximum intensity is always kept.

Another important aspect is the connectivity of these devices: every unit shares information on a network, which plays a control function (Internet of Thing architecture). This feature allows to apply also predictive algorithms to increase the intensity of light in the parts of the cities with more traffic, or more simply to adjust the luminosity to the current time, weather, and season.

The amount of power that can be saved depends on different factors, like the type of solution applied, the amount of traffic, the morphology of the city and the geographic location, that changes the weather and the amount of sunlight along the year. However, the saved power goes roughly from the 30% to the 65%[2,3,4,5] (maximum saving is obtained with motion detection sensors).

The usage on large scale of these systems may be a way to cut CO_2 emissions in a not negligible way. Installing smart streetlights in every city in the world can lead to achieve from 3.6 % to 7.2% of the goal of cutting the 50 % of greenhouse gas emissions.

Economic evaluation

Smart streetlights are surely an effective solution to cut down CO_2 emissions, but for them to be also feasible, these systems must also be economically affordable.

Smart streetlights need high investments at the beginning to be installed, but the saved energy can make them economically worthwhile over a long period of time.

To evaluate the investments needed for these technologies, first of all, it is necessary to check where the costs come from. First of all, on each pole is mounted a unit that requires some hardware. Some experiments use *Rasberry*[6] board to implement the logic control. The cheapest one that can be used is *Rasberry Pi Pico*, which costs roughly 5€ (but probably it will be substituted with a dedicated board). To connect the device to a network (using the LoRaWAN protocol) a module of the cost of 5€ is needed.

Then a dimmer driver for the LED lamp is needed, and it cost roughly 15€ (100W). If we want to mount a proximity sensor in the unit, the cost for a long range PIR sensor is about 10€.

The case price, of the light sensor, and of the low-voltage power supply, are negligible compared to other components.

Hence, each unit may cost 35€, but the price may be lower due to large-scale manufacturing of these devices.

An important point is the possibility to install these units without substituting the already existing lamps. It is useful in the case of already existing LED lamps, saving about 110€.

In second place, the management system has two main components: the cloud and the software[7]. The cloud for manage Internet of Things can costs less than one euro per device. Instead, the software price is between 30,000 to 50,000€. However, the number of streetlights in a city is in the same order of magnitude, and hence the management system for these system costs in the end some only some euros per device, probably 10€ in the worst case scenario.

In the end, some physical installation is required. These devices must be installed by professional workers with a special truck and it costs 110€ per light[8], that may be the major contribute if the lamp is not replaced.

In the end, the initial cost for upgrading a standard streetlight with a PIR sensor is about 155€ (265€ if we also have to replace the old lamp).

In the following years the other management costs are the electricity consumption and the eventually replacing of the lamps.

Scenarios evaluation

Now we can evaluate four scenarios in a time period of 20 years:

- **Scenario 1 (reference):** all streetlights work in the traditional way with sodium vapor lamps. The average lifespan for this type of lamp is between 6 and 8 years, hence, the lamps must be replaced roughly three times in the considered time period. Substitute each sodium lamp cost between 60 to 70€ plus the labor cost (110€).

- **Scenario 2 (second reference):** all streetlights work with already installed LED lamps. The lifespan of this type of light is about 30 years, so the number of lamp replacement is negligible in the considered time window.

- **Scenario 3:** the sodium lamps of each streetlight are replaced with a LED lamps

- **Scenario 4:** the old lamps are replaced and the dimming function is added, reducing 30% of electricity consumption.

- **Scenario 5:** the old lamps are replaced, the dimming function is added, and it works based on data collected by proximity sensors. This features saves 60% of electric power.

  The cumulative cost for each scenario are summarized in **Table 1**. In **Figure 1** are shown the costs to replace sodium lamps. **Figure 2** shows the costs for upgrading LEDs to smart streetlights.

Scenario	Cumulative cost in 20 years per streetlight	CO_2 due to electricity per streetlight (tonnes)
1 - Sodium light	1400€	4.6
2 - Already installed LEDs	700€	2.3
3 - Installing LEDs	920€	2.3
4 - Installing smart lights 30% saving (with no lamp replacement)	750 € (640€)	1.6
5 -Installing smart lights 60% saving (with no lamp replacement)	550€ (440€)	0.93

Table 1. Emission and cost for different type of streetlight. The prices and emissions are calculated assuming that one kWh costs 0.12€ and produces 400g of CO_2 .

From the data, it can be observed that substituting old sodium lamps is economically worthwhile because it is the most expensive solution. Investing in most efficient technologies can lead to a payback in only 3 years despite the initial costs.

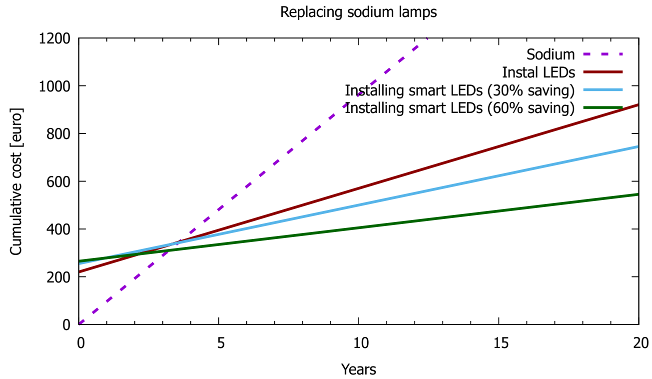

Figure 1. Cumulative costs for a single streetlight as a function of time.

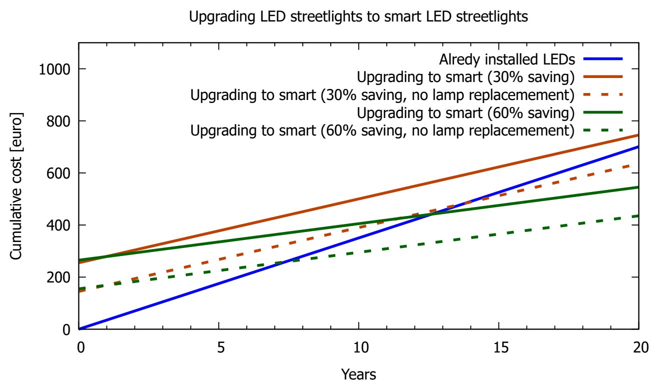

Figure 2. Cumulative costs for a single streetlight as a function of time. Comparison between different LED technologies.

Due to moderate saving with simple LED lights, upgrading this type of solution with smart streetlight units is economically worthwhile over a longer time period. If it is possible to use the already used LED lamps, the payback time is between 7 and 13 years. Otherwise, it is between 13 and 24 years, making this approach unfavorable.

The actual trend is to replace old sodium lamps with newer LED lights, that is surely positive both in environmental end economic terms, but is not the most efficient thing to apply.

In view of a future in which smart streetlights are widely used, upgrading today only the light bulbs is in a certain sense wasting money. In fact, one day smart streetlights will be installed, and in the end, the labor costs will be paid twice. Or worse, if it is not possible to use the already installed LED lamps a unit that includes a new lamp must be mounted, increasing prices.

Hence, it is better to include the installation of smart streetlights in an already existing program to upgrade old light bulbs to LEDs.

Conclusion

Smart streetlights seem a promising solution to cut down carbon emissions related to public illumination. The saved energy also makes public bill smaller, making these solutions also economically worthwhile despite the high initial investments.

The process for improving public illumination efficiency can be speeded up avoiding the intermediate steps of replacing old lamps with LEDs and jumping directly to smart LED streetlight. This needs one installation processes instead of two, leading to save money, energy and avoiding CO_2 emissions.

However, it is also economically and environmentally worthwhile to upgrade already existing LED streetlights making them smart with sensors and connectivity, but only if we are able to install a module that controls the already existing streetlights.

References

1. UNEP. The rapid transition to energy efficient lighting: an integrated policy approach. https://www.unep.org/resources/report/rapid-transition-energy-efficient-lighting-integrated-policy-approach (2013).
2. F. Sanchez-Sutil, A. C.-O. Smart regulation and efficiency energy system for street lighting with lora lpwan. *Sustain. Cities Soc.* **20**, 102912, DOI: https://doi.org/10.1016/j.scs.2021.102912 (2021).
3. Marino, F., Leccese, F. & Pizzuti, S. Adaptive street lighting predictive control. *Energy Procedia* **111**, 790–799, DOI: https://doi.org/10.1016/j.egypro.2017.03.241 (2017).
4. Kovács, A. *et al.* Intelligent control for energy-positive street lighting. *Energy* **14**, 40–51, DOI: https://doi.org/10.1016/j.energy.2016.07.156 (2016).
5. Tvlight. Starry nights on texel from intelligent lighting to energy neutrality. https://tvilight.com/it/case-study/starry-nights-on-texel/ (2016).
6. Omkar V Ambre, G. K. R. A. H., Omkar Devalkar. Smart street light system. *Int. J. Adv. Res. Sci. Commun. Technol.* **3**, 203–207, DOI: https://doi.org/10.1016/j.energy.2016.07.156 (2023).
7. Muts, I. The cost of iot: Ready-to-use vs. custom iot solutions. https://euristiq.com/cost-of-iot/ (2023).
8. Gong, T. How much does a street light cost? https://www.zgsm-china.com/blog/how-much-do-the-street-lights-cost.html (2023).