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# Public lighting energy consumption in Slovenian municipalities from 2007 to 2011

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**Abstract.** The paper presents an overview of public lighting energy consumption of (road and urban lighting) in Slovenian municipalities between 2007 and 2011. It discusses significant improvements in the quality of public lighting resulting from the increasing awareness of the importance of public lighting and technological possibilities available on the lighting market. Three case studies of recent lighting renovations in Slovenian municipalities are analysed to enable assessment of energy consumption reduction one can expect from increasing efficiency of lighting installations.

**Keywords:** public lighting, road lighting, municipalities, energy consumption

## 1 INTRODUCTION

Nowadays, public lighting is a commodity without which it would be difficult to imagine the contemporary world. It includes road lighting, lighting of pedestrian zones, façade and cultural heritage lighting as well as other public areas such as parking lots, underpasses and sports facilities. It doesn’t include lighting of private areas such as gardens, parking lots and similar.

Public lighting can also be defined as lighting paid for by public institutions such as municipalities. The institutions managing the Slovenian state roads are DARS and Slovenian Road Agency, which is part of the Ministry for Infrastructure and Spatial Planning. However, the share of state-road lighting-energy consumption is relatively small compared to the energy consumed for lighting municipal roads. It is less than 10 % [1].

Public lighting represents a relatively small proportion of the overall energy consumption in the country as it amounts to around 0.7 % [1]. The effort in reducing it, however, offers significant impact especially as public lighting is often the biggest public energy consumer in a municipality. Furthermore, investment in public lighting tends to have a quick payback time especially when the lighting equipment is rather obsolete. The payback time of a relatively new lighting installation, tends to be longer of course. This has made the pace of public lighting renovation to quicken markedly in the last couple of years in Slovenia. Moreover, the Lighting Pollution Decree (Decree of maximum values of light pollution (Uredba o mejnih vrednostih svetlobnega onesnaževanja; Official Gazette of RS no. 81/2007, modifications 109/2007 in 62/2010) binds operators of lighting systems in the country to comply with various specifications imposed on performance characteristics of luminaires, lighting pollution, distribution and consumption. For municipal lighting the requirements most challenging to comply with are regarding lighting energy consumption and performance characteristics of the luminaires.

At the Faculty of Electrical Engineering we have been following the development of public lighting for several years. In this paper we will present results of two studies in public lighting. One was conducted in 2007 and the other in 2011. They both provide focused data on energy consumption. The 2007 study was made with the help of municipal financial departments and the 2011 study was based on Lighting Plans adopted according to the Lighting Pollution Decree. As the Decree is such an important part of lighting industry in Slovenia, we will briefly present it in the following chapter.

## 2 LIGHTING POLLUTION DECREE

The Lighting Pollution Decree has enforced several changes in the field of lighting design, installation and maintenance. As to municipal lighting, the most far-reaching requirement is the maximum allowed annual lighting-energy consumption. It is set at 44.5 kWh per inhabitant per year. The other and perhaps even more radical one, is the requirement of zero upward-light output ratio (ULOR). To comply with it, a large portion

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of road luminaires have to be removed from use and banned from the market. The exceptions concerning public lighting are:

- When lighting the pedestrian zones in the vicinity of a cultural heritage object or building, luminaires that have ULOR of up to 10 % may be used, provided that the power of the luminaire is less than 20W and that the illumination of the surface lit by the luminaire is less than 2 lux;
- When the luminaire is part of a cultural heritage object itself, there is no ULOR limitation;
- When lighting outdoor sport facilities (for example outdoor basketball court or soccer field) ULOR of up to 5% is allowed, but only until 10pm or 1 hour after the end of the event.

The Decree of course includes several other requirements, the extent of which is, however, much too large for this article.

## 3 PUBLIC-LIGHTING ENERGY CONSUMPTION IN SLOVENIAN MUNICIPALITIES

In 2011 we started gathering the Lighting Plans of individual municipalities. Operators of lighting systems consuming more than 10 kW have to produce a Lighting Plan containing the following information:

- Location of the lighting installation and detailed location of the light source;
- Annual energy consumption, combined electrical power, number of installed luminaires and their ULOR;
- The overall length and surface of lit roads and other public areas when the lighting installation is intended for road or public area lighting;
- Surface area of the façade or cultural heritage building or object to be lit;
- Advertising surface area and electrical power of all the light sources or luminaires used for advertising purposes.

In our study we used Lighting Plans of municipalities who have already adopted them. There are some who still haven't managed to draw them and while some do have similar documents, most of which don't provide all the data required by the Decree. The most commonly missing data are those about the length of the lit roads, surface areas of lit cultural heritage buildings and surface areas of lit public areas. We gathered data about the number of installed luminaires, their combined electrical power and annual energy consumption from other documents as well in case the municipality didn't produce the Lighting Plan yet.

Data for 83 municipalities (40% of all the municipalities) were collected. In the 83 municipalities live 52% of all inhabitants of the country, while the surface area they cover is 42% of the overall country surface area. Only 50 had data about the length of their lit roads and knew the number of installed luminaires, total electric power consumed by their luminaires and annual energy consumption for public lighting. These data are represented in Table 3.1.

Most of the municipalities produced their Lighting Plan in 2009 and 2011 as shown in Figure 3.1.

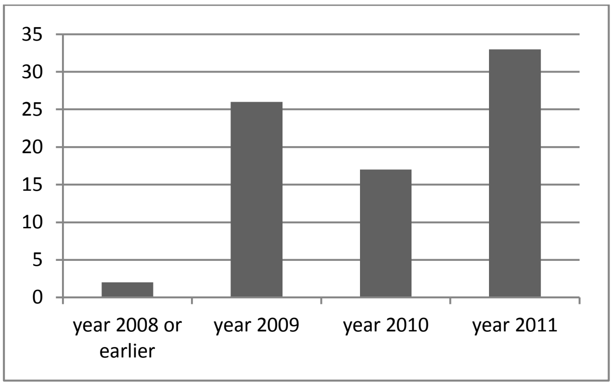


Figure 3.1: Year of Lighting Plan procurement year.

Based on the above data we calculated the average energy consumption per inhabitant (63.57 kWh/inhabitant), average electric energy of the luminaire (153.86 W) and average energy consumption per lit kilometre of the road (27.834,9 kWh/km).

Before obtaining the data, we assumed that public lighting of most of the municipalities that had adopted the Lighting Plan had been recently renovated, which could have, to a certain extent, distorted the data. However, it turned out that there is no significant correlation between the time the lighting was renovated and the existence of the Lighting Plan. Therefore we think the data obtained in this way can be applied to and averaged to the whole country.

Table 3.1: Energy consumption for public lighting in Slovenian municipalities.

| | ***Average luminaire power*** *[W]* | ***Consumption per inhabitant*** *[kWh/inh]* | ***Consumption per lit km of the road*** *[kWh/km]* |
|---|---|---|---|
| **Cities** | 129.49 | 63.13 | 20,812.4 |
| **Other** | 155.81 | 63.90 | 37,086.4 |
| **Sum** | **153.86** | **63.57** | **27,834.9** |

## 4 COMPARISON WITH THE 2007 DATA

In 2007, we conducted a study similar to the one described above. The data provided by financial departments of the municipalities from paid electricity bills and power consumption. The data were consumed energy for public lighting and the number of inhabitants. After calculating the annual consumption per inhabitant [kWh/inh], the average annual consumed energy per inhabitant for the whole country was calculated. This turned out to be 75,75 kWh per inhabitant. The average of the 11 urban municipalities, was a bit higher; 78.2 kWh per inhabitant. The average of the rest of municipalities was 73.8 kWh per inhabitant.

It was seen that the energy consumption for public lighting had decreased from 75.75 kWh/inhabitant in 2007 to 63.6 kWh/inhabitant in 2011, which is some 16% reduction.

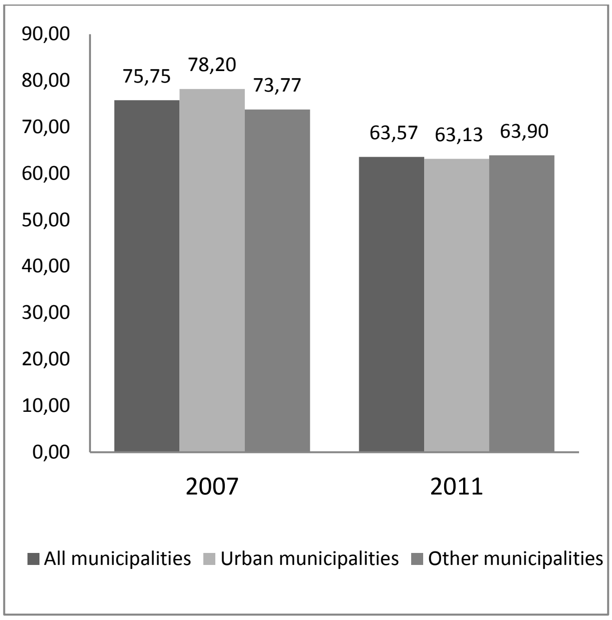


Figure 4.1: Differences in energy consumption from 2007 to 2011.

Figure 4.1 shows the amount of saving that can be expected from the public-lighting renovations. Of course, the saving depends on the state of lighting installations before renovation. If the lighting technology used before renovation is relatively old (obsolete reflectors, inefficient light sources and degraded diffusers) saving will be bigger.

In 2007 study we also analysed the power consumption for lighting the state-managed roads; it was 6.88 kWh/inhabitant. To sum up, the overall energy consumption in 2007 was 82.59 kWh/inhabitant.

## 5 ENERGY CONSUMPTION REDUCTION POSSIBILITIES

In the following chapter we will present three cases of public lighting renovations which will explain the extent of reductions in energy consumption that can be expected.

### *5.1 Renovation in Celje municipality*

The Celje municipality with its 48.000 inhabitants is one of the biggest municipalities in Slovenia. Until 2008 they renovated most of their public lighting infrastructure. According to the data by Elektrosignal, which manages most of the public lighting in the municipality, there were 4080 luminaires installed, which means one luminaire per every 12 inhabitants. Before the renovation the luminaires had mostly 400 W, 250 W and 125 W light sources as shown on the Table 5.1, where HPM denotes for metal-halide lamp and HPS denotes high pressure sodium lamp.

Table 5.1: Light sources in Celje prior to renovation

| *Light source* | *Power [W]* | *Number of light sources* |
|---|---|---|
| **HPS or HPM** | 400 | 850 |
| **HPS or HPM** | 250 | 620 |
| **HPM** | 125 | 2610 |
| **SUM** | | **4080** |

The overall electric power of all the light sources is 821.25 kW. Combined with the losses in the ballasts, the electric power is some 862 kW. Based on the average of 4300 working hours per year of public lighting, the overall energy consumptions is 3.706.660 kWh, which is 77 kWh/inhabitant.

The renovation included all the luminaires, for which all the lamps were replaced by the more efficient high pressure sodium (HPS) lamps. The 400W HPM lamps were replaced by the 250W HPS lamps, 250W HPM lamps by 150W HPS lamps and 125W HPM lamps by the 36W fluorescent lamps. The number of light sources after the renovation is shown in Table 3.1Tables 3.1 and 5.2.

Table 5.2: Number of light sources after renovation (MH stands for Metal Halide)

| *Light source* | *Power [W]* | *Number of light sources* |
|---|---|---|
| **HPS** | 250 | 850 |
| **HPS** | 150 | 620 |
| **Fluorescent** | 36 | 1840 |
| **MH** | 32 | 770 |
| **SUM** | | **4080** |

As seen from the above data, the electric power of the light sources is 389.45 kW or 419 kW after adding the losses in the ballasts. At 4300 average working hours per year, the annual energy consumption is estimated at 1.801.700 kWh or 37 kWh per inhabitant, which means the energy consumption dropped to 48% after the renovation.

### *5.2 Estimation of energy-consumption saving in the Duplek municipality*

The Duplek municipality lies in the eastern part of Slovenia and it has 6580 inhabitants, which means it is one of the minor Slovenian municipalities. In 2009, the municipality ordered a study of the development of public lighting [3]. The study analysed the available technology and estimated the potential savings gained by applying them.. Most of the light sources in the municipality at the time were 125W HPM.

Table 5.3: Light sources in the Duplek municipality

| *Light source* | *Power [W]* | *Number of sources* |
|---|---|---|
| **Compact fluo** | 20 | 29 |
| **MH** | 25 | 16 |
| **Fluorescent** | 36 | 23 |
| **MH** | 70 | 237 |
| **HPM** | 125 | 547 |
| **HPS** | 150 | 120 |
| **HPS or HPM** | 250 | 31 |

Based on the above data, the total power of all the light sources is estimated at 112.523 kW or, after calculating the power losses the ballasts at 121.534 kW. At 4300 working hours, the annual energy consumption for public lighting is 522.594 kWh, which means 79.42 kWh/inhabitant.

The municipality estimated how much energy would be saved if all the mercury lamps were replaced by HPS ones.

Table 5.4: Light sources after renovation

| *Light source* | *Power [W]* | *Number of sources* |
|---|---|---|
| **Fluorescent** | 18 | 23 |
| **HPS** | 50 | 1 |
| **HPS** | 70 | 828 |
| **HPS** | 150 | 145 |
| **HPS** | 250 | 6 |

The total power of light sources after renovation would be 81.67 kW or 88.21 kW with the ballast losses accounted for. Annual energy consumption would be 379.294 kWh, which means 57.64 kWh/inhabitant. The saving would be some 28% per year.

Compared with the Celje municipality the relatively smaller savings are due to a larger proportion of HPS in the currently used light sources unlike is the case in Celje municipality.

### *5.3 Estimation of energy consumption savings in the Mozirje municipality*

Having only some 4000 inhabitants, Mozirje is an example of a minor municipality. Until 2007 they had renovated most of their public lighting and in 2007 they analysed energy consumption to estimate the possibilities of further energy savings. At the time of our analysis there were 208 luminaires installed in the municipality. This is almost half of the national average, which is one luminaire per 10 inhabitants. Most of the luminaires in the municipality are fluorescent lamps. The number of HPS is small. This is due to the traffic traffic on most of the municipal roads, which is not very heavy. An overview of the types of the used lamps in Mozirje is presented inTable 5.5

Table 5.5: Types of the used lamps in Mozirje municipality in 2007.

| *Light source* | *Power [W]* | *Number of sources* |
|---|---|---|
| **Compact fluo** | 23 | 88 |
| **Compact fluo** | 36 | 80 |
| **HPS** | 250 | 25 |
| **HPS** | 400 | 10 |
| **HPM** | 250 | 2 |
| **HPM** | 400 | 3 |
| **SUM** | | **208** |

The total electric power of all the installed lamps is 16.8 kW, which means 18.2 kW afteradding the ballast losses. At the 4300 average working hours this is 78.260 kWh, or 19.74 kWh/inhabitant. The average energy consumption per inhabitant is here much less than the national average, because of the low number of installed luminaires in the municipality.

To further decrease the energy consumption, the rest of the HPM lamps (5 luminaires) should be replaced with the HPS lamps. For example: 250 W HPM lamps should be replaced by 150 W HPS lamps and 400 W HPM lamps should be replaced by 250 W HPS lamps. Besides using more efficient lamps, a lighting control system, should be installed to further lower the light output and energy consumption during the time of less traffic. By doing so, the energy consumption would be decreased by some 10%, meaning the electric power would decrease from 18.2 kW to 17.6 kW.

## 6 COMPARISON WITH THE STATE IN OTHER EUROPEAN COUNTRIES

As part of our study, energy consumed by public lighting in Slovenia was compared with that consumed in some other European countries. The data for these countries were collected in 2007 [2] by Vito, Belgium, for the European Commission. The reliability of the method used by Vito, which also analysed the Slovenian data, was lower than the one of the method we used both in 2007 and in 2011. It is for this reason that in our comparison we used the data we collected in 2007.

We calculated two additional indicators of public lighting sustainability which are consumption per square kilometre of surface area and consumption per kilometre of the road. For the latter it must be stressed that the kilometre of the road means the whole length of the road and not just the lit part, which is the case at the lighting plans as specified by the light pollution Decree in Slovenia.

Table 6.1: Indicators of public lighting sustainability for the compared European countries.

| *Country* | *Consumption per inhabitant [kWh/inh]* | *Consumption per surface area [kWh/km²]* | *Consumption per kilometre of road [kWh/km]* |
|---|---|---|---|
| Sweden | 106,38 | 2.222,40 | 7.094 |
| Ireland | 27,74 | 2.037,41 | 448 |
| Slovenia | 82,59 | 8.147,42 | 4.229 |
| France | 79,24 | 9.062,98 | 4.831 |
| Poland | 62,83 | 7.675,46 | 6.246 |
| Germany | 42,00 | 9.681,78 | 1.509 |
| The United Kingdom | 39,81 | 10.163,79 | 5.926 |
| Belgium | 90,55 | 32.625,79 | 6.584 |
| The Netherlands | 46,00 | 18.166,93 | 5.947 |
| EU 25 | **51** | **5.987,30** | **3.565** |

The most commonly used indicator in assessing about light pollution is the power consumption per inhabitant. However, this indicator has an inherent flaw, for not considering population density. Public lighting is designed based on the surface area and traffic parameters of the roads and other public surfaces. This means the cities and countries with a higher population density, for example Germany, the United Kingdom and the Netherlands, will tend to have lower consumption per inhabitant than sparsely populated ones [4].

This trend can be easily seen in Figure 6.1, where the only exceptions are Ireland and Belgium. The relatively higher power consumption rate per inhabitant in Belgium can be explained by the fact that they light a much higher proportion of their roads than other countries.

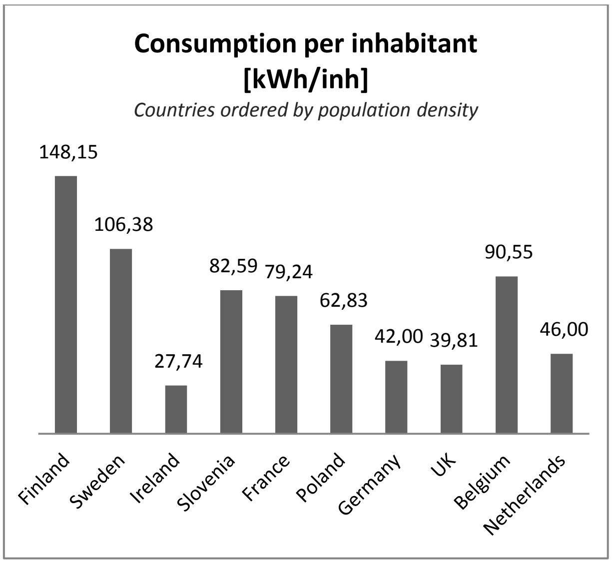


Figure 6.1: Energy consumption per inhabitant for public lighting. Countries are ordered according to their population density. The trend of falling consumption per inhabitant with the increasing population is clearly visible.

Consumption per surface area has a different kind of flaw; it prefers countries with large areas mostly devoid of people. Countries with a relatively even distribution of population density, such as France, Poland and the Netherlands, tend to perform worse than countries with large empty areas, such as Sweden and Finland.

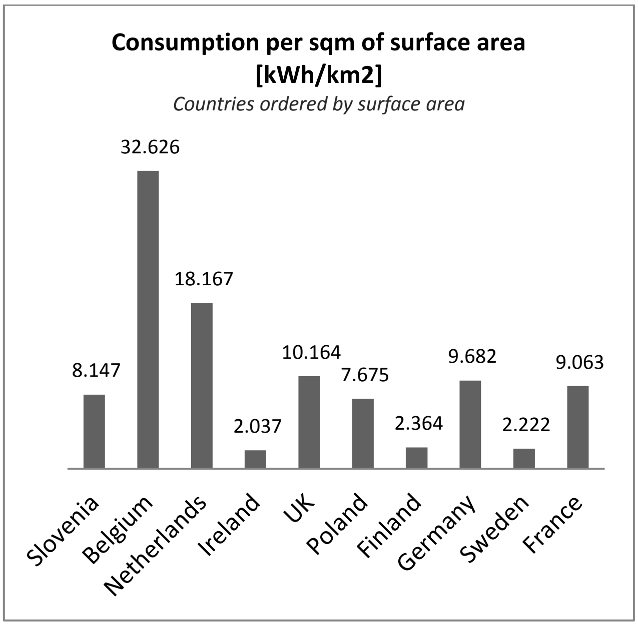


Figure 6.2: Annual energy consumption for public lighting per square km of surface area. Countries are ordered according to their surface area.

Following the above, we are convinced that the best indicator of sustainability and efficiency of public lighting is energy consumption per kilometre of roads. This indicator concerns road lighting, on which planning and designing of public lighting is based . It doesn't include lighting of squares, parks and other public surfaces, as their share in public lighting is relatively small. It should be noted that energy consumption per lit kilometre of roads is just informativeas it is almost impossible to obtain the data about the lengths of the roads that are lit.

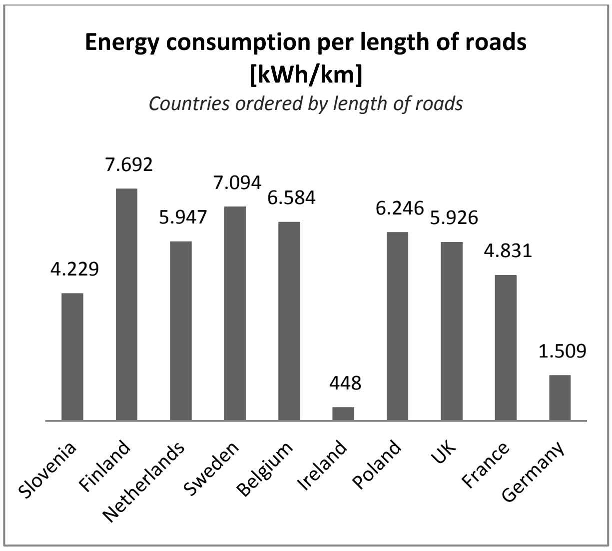


Figure 6.3: Energy consumption per kilometre of roads.

## 7 CONCLUSION

Public lighting in Slovenia has experienced extensive renovations which can be, to no small extent, attributed to the implementation of Lighting Pollution Decree, giving rise to a significant number of renovations in several Slovenian municipalities.

As shown in the Chapter 5, the energy saving ranges from some 10% when renovating relatively modern lighting installations to some 50%, when renovating very obsolete and deteriorated lighting installations. Similarly, the investment payoff time is from 3 years to 15 years respectively

On the basis of these data a conclusion ca be drawn, that efficiency and sustainability of public lighting has been significantly improved.

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