



Table of contents

Table of contents	1
List of tables	2
List of diagrams	3
1 Introduction	4
1.1 General.....	4
1.2 Total electricity demand	4
1.3 CO ₂ emissions calculation	6
2 Input from the cities	6
3 Assumptions	8
3.1 Ballasts.....	8
3.2 Power factor	8
3.3 Operation time.....	8
3.4 Distribution losses	8
3.5 CO ₂ emissions.....	9
4 Presentation of the model	10
5 Results	12
5.1 Raciechowice (Poland)	12
5.2 Slovenska Bistrica (Slovenia).....	12
5.3 Voru (Estonia)	13
5.4 Riga (Latvia).....	13
5.5 Dej (Romania)	14
6 Conclusions.....	15
7 Annex	17

List of tables

<i>Table 1: Total losses in electricity net from power plant to final consumption.</i>	9
<i>Table 2: Energy resources for electricity production</i>	9
<i>Table 3: CO₂ emissions from fuel to electricity conversion.</i>	10
<i>Table 4: Energy consumption and CO₂ emissions for Raciechowice</i>	12
<i>Table 5: Energy consumption and CO₂ emissions for Slovenska Bistrica</i>	13
<i>Table 6: Energy consumption and CO₂ emissions for Voru</i>	13
<i>Table 7: Energy consumption and CO₂ emissions for Riga</i>	14
<i>Table 8: Energy consumption and CO₂ emissions for Dej</i>	14
<i>Table 9: Expected CO₂ emissions reduction for the 3 cities</i>	14

List of diagrams

Diagram 1: CO₂ emissions for the 5 cities15

1 Introduction

1.1 General

This report is developed in the framework of the "*Bottom-Up to Kyoto*" project, which is co-funded by the Intelligent Energy Europe Programme. The aim of this report is to present the potential of reduction in CO₂ emissions of a municipality attributable to street lighting, when a renovation is foreseen. The project focuses on 5 European Municipalities, namely Voru (Estonia), Slovenska Bistrica (Slovenia), Raciechowice (Poland), Dej (Romania) and Riga (Latvia). For 3 of them, complete data were collected, while for the other two, the CO₂ reduction potential will be based on assumptions.

For the purpose of the CO₂ emissions assessment, an estimation of the electricity consumption due to street lighting took place. The calculations were based on the data that the 5 cities provided to the consortium; the data provided by the 5 cities do not necessarily correspond to the entire street network.

For the assessment of the CO₂ emissions, the following aspects were taken into account: the electric loads from street lighting (energy demand), the losses due to the ballasts and the transmission system (electricity grid), corresponding to the electric demand attributable to lighting.

For the calculations, special excel worksheets were used. The data given were introduced in the worksheets and in cases where data was not provided, assumptions were made.

1.2 Total electricity demand

The total electricity consumption due to street lighting in each city is the sum of the energy consumed for the lighting of the lamps plus the energy that is converted to heat by the ballasts (losses).

However, except from the losses at the lighting poles, additional power losses take place on the distribution network (cables, transformers etc), as well as in the power production plants (internal losses). This amount of energy is taken into account as well, as it is considerable; it is estimated that for each 100 KWh required (demand) in the consumption side, a total amount of energy that varies from 6 to 20 KWh is lost within the distribution network and consumed inside the power stations.

In figure 1 a schematic presentation of the energy flow from the power plant to the final consumption is given.

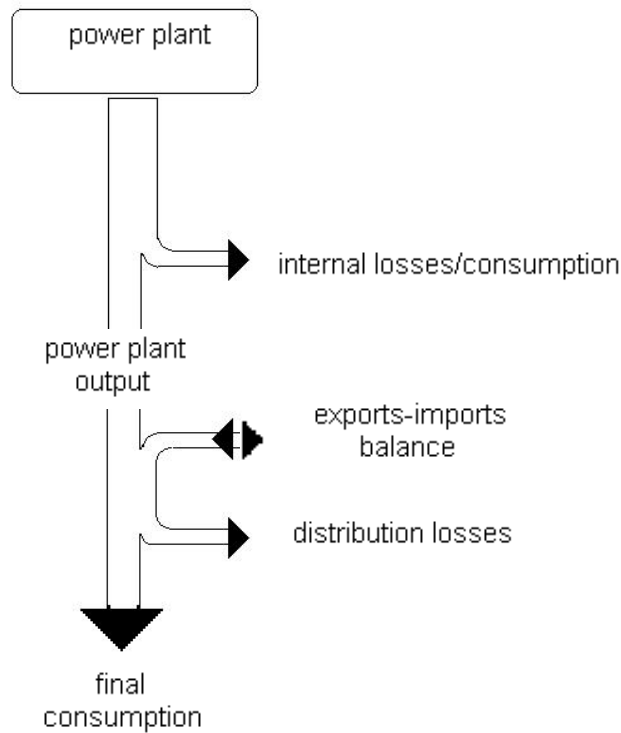


Figure 1: Schematic power flow

The schematic power flow is described below: Electric energy is produced in the power plants. A small amount of the electricity produced is consumed inside the power stations and thus the power plants' output is the net amount of electricity that is introduced to the electricity grid. There is also electricity trade to/from other countries though, resulting to a net import-export balance. Therefore, the total amount of energy distributed to the final consumers through the electricity grid is the net electricity production plus the import-export balance. Due to the electric resistance of the cables, transformers etc, a percentage of the energy produced do not reach the final consumers, due to distribution and other losses. Therefore the final consumption is the sum of the net output of the power plants plus the imports-exports balance minus the distribution losses.

In order that the total energy produced for the satisfaction of the final energy demand is calculated, the following factors a, b are used:

$$a = \frac{\text{power plant output}}{\text{gross electricity production}}$$

$$b = \frac{\text{final consumption}}{\text{final consumption} + \text{distribution losses}}$$

1.3 CO₂ emissions calculation

The CO₂ emissions due to the electricity production varies from one country to another as the energy sources used in each country for electricity production are different and the efficiency of the power plants varies depending on the technologies used. Therefore, based on the data collected on the share of the fuels (e.g. coal, oil, natural gas, renewables etc) on the electricity production of each country, the CO₂ emissions produced are assessed.

It is assumed that the power plants for electricity production from renewable energy sources or nuclear fuels do not contribute to the CO₂ emissions and thus the respective emissions factors are considered negligible.

2 Input from the cities

The assessment of the electricity consumption and the CO₂ emissions took place for the five European cities, namely Dej (Romania), Voru (Estonia), Slovenska Bistrica (Slovenia), Raciechowice (Poland) and Riga (Latvia). The calculations were based on the data that the municipal authorities provided and concern outdoor lighting installations. Outdoor installations refer to street lighting, mainly squares, roads and avenues. Data was collected for the existing situation in all five cities, as well as for the post-investment situation (new lamps foreseen to be installed) in the three towns Voru, Slovenska Bistrica, Raciechowice.

2.1 Type of data

For the collection of the necessary input, a specific questionnaire was developed and used and the five municipalities filled in the questionnaire the data available.

More specifically, information about the number, type and power of the lamps installed is requested, as well as the number and type of starter-ballast devices and the power

losses of each lamp. Moreover, data on the operation time of the lighting equipment was provided and the value of the power factor was identified.

In case of missing data, in order that the total energy demand and losses are estimated and the CO₂ emissions are assessed, assumptions were made and are presented in a separate paragraph.

2.2 Lamps

The type of the lamps used depends on the installation. For outdoor installations, the following basic types of lamps are used:

- Sodium vapor lamps (high or low pressure)
- Mercury vapor lamps
- Metal Halide (and other halogen lamps)
- Fluorescent lamps

2.3 Ballasts

Except from incandescent lamps, all other types of lamp are equipped with a regulating device for starting and controlling the electric current within them. There are two main types of ballast: electromagnetic and electronic ballast. The power loss in the case of electromagnetic ballasts is up to 20% while the losses at the electronic ones are much lower, up to 5%.

2.4 Power factor

$\cos\phi$ is the power factor of the installation and indicates how much electric power cannot be used in the final consumption (reactive power). $\cos\phi$'s maximum value is 1 (100%). The lower $\cos\phi$ is, the required energy for a system to operate is increased and thus, energy losses are higher.

All outdoor lighting lamps (street lamps) are manufactured with an internal set for correlation of $\cos\phi$, in order to obtain satisfactory values of $\cos\phi$ (≈ 0.95), according to the standard IEC EN 61048/49.

3 Assumptions

For the process of data, a few assumptions were necessary to be done, due to lack of detailed and analytical technical data.

3.1 Ballasts

A typical 15-20% loss for non incandescent lamps was assumed and was taken into account whenever there was no data for the losses at the ballasts.

3.2 Power factor

A $\cos\phi$ value of 0,9 is assumed for street lighting as all types of street lamps are manufactured with a provision for a $\cos\phi$ correction.

3.3 Operation time

The cities provided a time schedule for the operation of the lighting installations, or a total number of hours per year.

3.4 Distribution losses

For the estimation of the distribution losses within the electricity grid of each country, the factors a and b identified above (paragraph 1.2) were used. Factor c, which is defined below, represents the ratio of the total gross electricity production to the total energy consumption, describing the energy losses that occur between the power plant and the final consumption.

$$c = \frac{1}{a \times b}$$

The factor c is calculated for the five countries and is presented in table 1.

Country	City	Production to total consumption ratio (Factor c)
Romania	Dej (Cluj)	1,231
Estonia	Voru	1,325

Report on the assessment of CO₂ emissions in European municipalities

Slovenia	Slovenska Bistrica	1,148
Poland	Raciechowice	1,254
Latvia	Riga	1,193
Source: EUROSTAT 2005		

Table 1: Total losses in electricity net from power plant to final consumption.

The differences that are shown in the table above are due to the fact that the type and the age of the power plants, the mix of energy sources in the gross production and the installations (e.g. electricity grid) are different in each country and the national regulations for cables, transformers and distribution voltage may differ as well.

3.5 CO₂ emissions

For the assessment of the quantity of CO₂ emitted which is attributable to lighting in the five cities, the special characteristics of each country were taken into account. As in each country different technologies and different energy sources are used for electricity production, the fuel mix was identified and emissions factors were developed. In the table below, the share of the energy resources for electricity production is shown:

Country	City	Coal/ lignite	oil	Natural gas	nuclear	renewable	other
Romania	Dej (Cluj)	38,00%	3,90%	19,00%	9,80%	29,20%	0,00%
Estonia	Voru	92,50%	0,30%	6,60%	0,00%	0,50%	0,00%
Slovenia	Slovenska Bistrica	34,00%	0,30%	2,30%	35,70%	27,60%	0,00%
Poland	Raciechowice	91,90%	1,60%	3,30%	0,00%	2,00%	1,00%
Latvia	Riga	0,00%	1,30%	30,60%	0,00%	68,20%	0,00%
Source: Eurostat (2004)							

Table 2: Energy resources for electricity production

Each energy resource has different contribution in CO₂ emissions. In table 3 the quantity of CO₂ emitted per kWh of electric energy is presented. As the specific energy production technologies used in each power plant are not known, the following assumptions were made:

- Coal/lignite/coke fuels steam production boilers for steam-turbine generators
- Oil fuels internal combustion diesel engines
- Natural gas fuels gas-turbine generators
- Nuclear power stations fuels steam-turbine generators
- Co-generation is not taken into account
- Under the “others” category unidentified energy resources are included whose contribution to CO₂ emissions is considered negligible
- Each type of fuel is considered to have the same quality and calorific value in all countries.
- The efficiency of a specific type of power plant is considered to be the same in all countries.
- In case that the contribution of imports in the gross electricity consumption is considerable (e.g. for Latvia), it is assumed that the imported electricity is produced through the same energy technologies as in the destination country

Fuel/source	Kg CO₂/kWh_e
Coal/lignite	0.9590
Oil	0.8186
Natural gas	0.4475
Nuclear ¹	0.0040
RES ²	0.0000
Source: Fuel and Energy Production Emission Factors, AEA Technology	

Table 3: CO₂ emissions from fuel to electricity conversion.

From the table above, it is clear that in countries where coal is the main energy resource for electricity production CO₂ emissions/kWh_e are high. In addition, it is shown that natural gas is the cleanest among the fossil fuels.

4 Presentation of the model

All data gathered was used as input for the model. The part of the model used for the calculation of the actual energy consumption and the estimation of the CO₂ emissions

¹ CO₂ is emitted not only during the electricity production procedure but also during the extraction and transportation of the fuel to the power station. Thus, even nuclear power has a small contribution in CO₂ emissions.

² As in most cases energy production from renewable energy sources has negligible CO₂ emissions, the respective emission factor is assumed to be zero.

consists of 3 worksheets. Each of the worksheets, the type of input inserted and the calculations made are briefly explained below. It has to be clarified that the model was developed in order to receive data from both office and street lighting sectors; the Municipalities that participate during the entire project's duration though have only focused on street lighting.

Worksheet A

Input

- Type of the lamps
- Power consumption of the lamps
- Type of ballasts and losses
- Operation time of each lamp
- Power factor of the installations

Calculations

- Total energy demand for indoor and outdoor lighting installations
- Total energy losses at the ballasts of the lamps and due to the $\cos\phi$ of the installation

Worksheet B

Input

- Ratio of the losses within the electricity distribution network to the final energy consumption

Calculations

- Total electric energy required to cover the demand for lighting

Worksheet C

Input

- Contribution of each fuel type to the electricity production for each country
- The CO₂ emissions that are produced from each energy resource for its conversion to electric energy

Calculations

- Total CO₂ production of each city for outdoor and indoor lighting separately
- Reduction of CO₂ emissions and energy savings

The calculation worksheets mentioned above are attached as Annex to this report.

5 Results

The results of the calculations for every city are given below and include –for the data provided- the energy demand, as well as the CO₂ emissions. The reduction of the CO₂ emissions refers to lamps that are replaced with more efficient ones.

5.1 Raciechowice (Poland)

Raciechowice provided data for street lighting from some major streets. The total number of lamps is 357 pc, most of which are vapor sodium lamps. The investment foreseen to take place concerns 353 lamps (percentage 98,9%). In addition, data was provided for ballasts and energy losses. The total time of operation provided for the lighting equipment is 3285h per year. Assuming that the value of $\cos\phi$ for the lighting installation is 0,9, the results of the calculations for energy consumption and CO₂ emissions are shown in table 5.

City	Population	Area (km ²)	Situation	Energy production required (kWh/year)	CO ₂ emissions (tones/year)
Raciechowice	5950	60,97	BEFORE	270.929,76	246,33
			AFTER	146.299,68	133,01
CO₂ emissions Reduction (%)				46,00%³	

Table 4: Energy consumption and CO₂ emissions for Raciechowice

5.2 Slovenska Bistrica (Slovenia)

Slovenska Bistrica provided data for outdoor lighting regarding 273 roads with a total of 2460 lamps, as well as for the type of lamps, the ballasts and energy losses.

Assuming a $\cos\phi$ value of 0,9, the results of the calculations with regard to the energy consumption and the CO₂ emissions are presented in table 6.

City	Population	Area (km ²)	Situation	Energy production required (kWh/year)	CO ₂ emissions (tones/year)
Slovenska Bistrica	22.893	260,1	BEFORE	1.423.178,15	484,22
			AFTER	799.008,00	271,85

³ Percentage of lamps changed 98,9%

CO₂ emissions Reduction (%)	43,90%⁴
---	---------------------------

Table 5: Energy consumption and CO₂ emissions for Slovenska Bistrica

5.3 Voru (Estonia)

Voru provided data outdoor lighting, where the total number of lamps is 689, mostly sodium and vapor lamps.

As operation time of outdoor lighting 3285 h are used (9 hours per day).

Also an assumption for the value of $\cos\phi$ was done as following:

- $\cos\phi = 0,9$ for outdoor installations

In table 7, the results of the calculations for the energy consumption and the CO₂ emissions are shown.

City	Population	Area (km ²)	Situation	Energy production required (kWh/year)	CO ₂ emissions (tones/year)
Voru	14.554	13,24	BEFORE	876.696,06	805,74
			AFTER	423.808,33	389,51
CO₂ emissions Reduction (%)				51,70%⁵	

Table 6: Energy consumption and CO₂ emissions for Voru

5.4 Riga (Latvia)

Riga provided data for indoor lighting for 60 public buildings, and also the type and wattage of each lamp, the type of the majority of the ballasts and the energy losses as well. The total number of the lamps is 53.334 pc. Riga also gave an analytical time of usage of each lamp and $\cos\phi$ value of the majority of the electrical installations. Table 4 gives the calculations on energy consumption and CO₂ emissions.

City	Population	Area (km ²)	Situation	Energy production required (kWh/year)	CO ₂ emissions (tones/year)
Riga	747200	307,17	BEFORE	6.156.256,5	908,50

⁴ Percentage of lamps changed 71,3%

⁵ Percentage of lamps changed 51,9%

			AFTER	N/A	479,78 ⁶
CO₂ emissions Reduction (%)				47,20%⁷	

Table 7: Energy consumption and CO₂ emissions for Riga

5.5 Dej (Romania)

Dej provided data for street lighting from some major streets. The total number of lamps is 1786 pc mostly of unknown type. In addition, data on the ballasts and the losses were provided. The total time of lighting operation is given about 4000h per year. Assuming that no incandescent lamps are used and that $\cos\phi$ is 0,9, the following calculations for the energy consumption and the CO₂ emissions were made.

City	Population	Area (km ²)	Situation	Energy production required (kWh/year)	CO ₂ emissions (tones/year)
Dej	38478	109,12	BEFORE	1.990.169	958,7
			AFTER	N/A	506,33 ⁸
CO₂ emissions Reduction (%)				47,20%⁹	

Table 8: Energy consumption and CO₂ emissions for Dej

The expected reduction of CO₂ in the 3 cities which provided specific data for the renovation of the street lighting system can be found in the following table:

Municipality	Expected CO ₂ reduction
Slovenska Bistrica	43,9%
Raciechowice	46,1%
Voru	51,6%

Table 9: Expected CO₂ emissions reduction for the 3 cities

⁶ Estimation of the reduction in CO₂ emissions if lighting system is renovated. Calculation based on average percentage

⁷ Average percentage

⁸ Estimation of the reduction in CO₂ emissions if lighting system is renovated. Calculation based on average percentage of the other towns

⁹ Average percentage

A summary of the expected reduction in the reduction of CO₂ emissions of the 5 cities are presented in the following diagrams. The data for Dej and Riga are based on a theoretical investment which would result to a CO₂ emissions reduction of 47,20%.

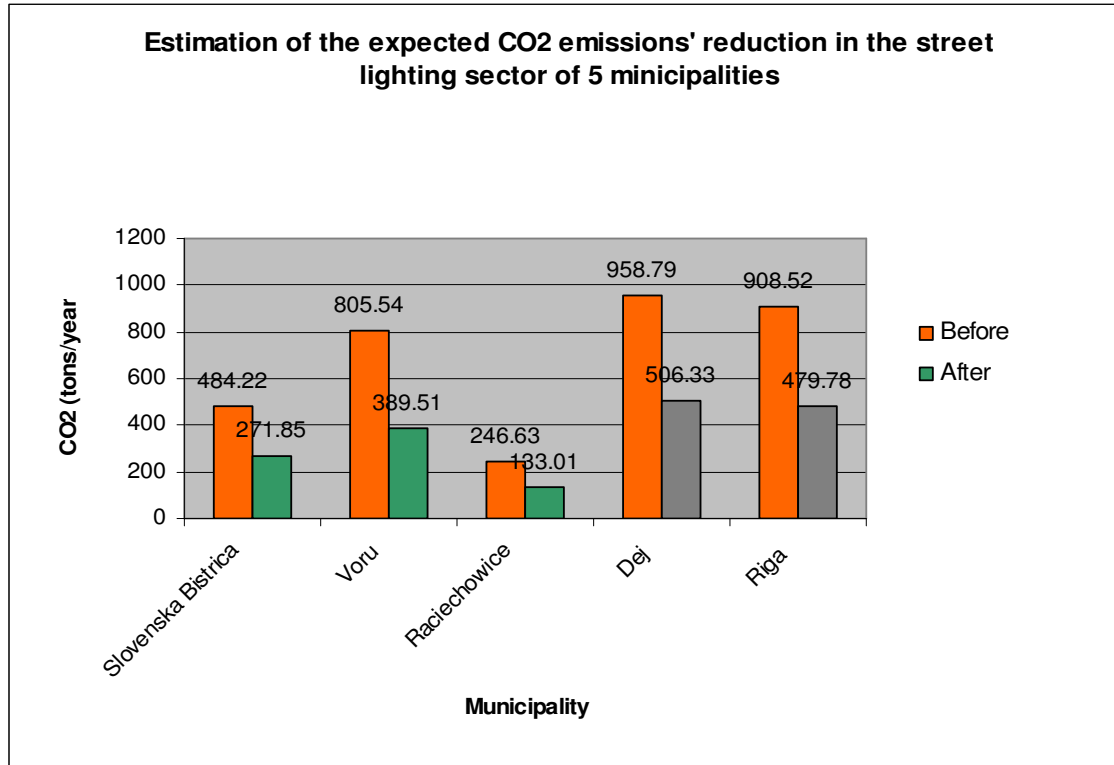


Diagram 1: CO₂ emissions for the 5 cities

6 Conclusions

In this report, the existing situation and the post-investment projection of the actual electricity consumption and the CO₂ emissions due to the street lighting in the 5 European cities were assessed.

Investments for energy saving and for an increase of the energy efficiency of the lighting sector are foreseen in 3 out of the 5 cities (namely Raciechowice, Slovenska Bistrica and Voru) and the results are based on the data on the renovation of the street lighting system. The expected reduction of CO₂ emissions varies from 44-52%. Therefore the renovation of the street lighting system in the three municipalities will result to considerably high reduction in CO₂ emissions, as well as to substantial economic benefits, as the operational cost of street lighting will also be reduced.

For the other two cities (namely Riga and Cluj (Dej)), the calculation was made on the basis of an average CO₂ reduction percentage, in order to demonstrate the potential for reducing CO₂ emissions with the municipalities area.

7 Annex

Calculation model (sheets A, B and C)