Project Title:

Energy Efficiency in Industry
Contract No. NNE/52/2002 "OPET CHP/DHC"

Work Package 5 • Task 4
Energy Efficient Lighting

DELIVERABLE no. D14:
Action Methodology and Design Study

August 2003

European Commission (Directorate-General for Energy and Transport)
"Action Methodology and Design Study"

Organisation: Black Sea Regional Energy Centre (BSREC) in collaboration with Research & Development Laboratory for Lighting of the Technical University Sofia
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ACTION METHODOLOGY

1. Survey of the production process and visual tasks in the department.
   ♦ Overview of manufacturing technology and ergonomic work conditions;
   ♦ Analysis of visual tasks:
     * Angular aperture subtended by an object for perception;
     * Contrast between the object and its background;
     * Speed of perception;
     * Relative duration of the visual works within the whole manufacturing process.
   ♦ Investigation of the character and reasons of production rejects;
   ♦ Assessment of the illumination influence on work efficiency and production accidents.

2. Assessment of the existing illumination in the department.
   ♦ Measurement of lighting parameters: average and minimum illuminance of the working places; minimum illuminance in the work shop;
   ♦ Evaluation of glare index and reflected glare;
   ♦ Determining fluorescent flicker, color of light, color rendering index and shadows;
   ♦ Specifications of the type, number, and positioning of luminaires and lighting sources, and their condition.
3. New Lighting Equipment Design

3.1. Specification of the Lighting norms:
- Average illumination of the room;
- Illumination of working places;
- Color of light;
- Color rendering index;
- Distribution of the luminous flux;
- Fluorescent flicker.

The illumination of the working surface will be specified in accordance to the European norms for indoor lighting: EN 12464/2002. The object size, contrast between the object and its background, as well as the speed of perception will be also considered for additional control.

3.2 The suitable lighting sources will be chosen through comparison between different type of lamps: tubular fluorescent, compact fluorescent and HID metal-halide.

The lighting-technical requirements for color of light and color rendering index will be considered also.

Preference will be given to the lamps having the highest luminous efficacy of any three types lighting sources mentioned above.

3.3 The luminaires are chosen according to the following requirements:
♦ Index of Protection (IP), consistent with the type of rooms and manufacturing process;
♦ High light output ratio of the luminaires;
♦ Appropriate light distribution curve, conformable to the positioning of luminaires and requirements for steady illumination, admissible discomfort glare index, and direction of light.
♦ Corrosion resistance of the luminaires;
♦ Easy maintenance of the luminaires;
♦ Esthetical design of the luminaires.

3.4 Electronic control gear (ballast) will be chosen under the following considerations:
♦ Three times lower own losses compared to conventional electromagnetic chokes;
♦ Basic solution of the light flicker;
♦ Extension of the lamps life.

3.5 The positioning of luminaires is determined by the following considerations:
♦ Architecture and construction design of the premises;
♦ Manufacture technology plan and workplaces location;
♦ Realization of the lighting norms by using minimum luminaires.

3.6 Calculation of the lighting equipment parameters based on selected lighting sources, type and positioning of the luminaires.
The average illuminance is calculated by taking into account multiple reflections and using the following programmes: "Calculus", "Dialux" and "Light cad".

3.7 Choosing lighting equipment control system having in mind:
- Daylight component of the integral illumination;
- People's occupancy in the room;
- Working process automation level.

3.8 Electrical installation design of the lighting equipment considering the chosen control modes:
- Choosing supply scheme and electrical tables position;
- Determining electrical installation configuration;
- Sizing of conductors' cross-sections and dimensioning of electrical installation;
- Choosing fuses, automatic devices and switching equipment;
- Power factor improvement and choosing the most favourable tariff for energy payment;

4. Assessment of energy and cost savings of the renovated lighting equipment:
- Calculation of the installed power of lamps and ballasts;
- Calculation of the annual energy consumption and annual energy costs;
- Determining the comparative Energy Efficiency indicators; 
  \[ \frac{W}{m^2}.lx \]
♦ Comparison between Energy Efficiency of the existing lighting system and renovated one;
♦ Calculation of the net present value (NPV) and IRR for cost savings evaluation of the renovated lighting equipment.

5. Ecology of the project solution
Estimation of annual amounts of green house gas emissions resulted from the consumed electric power for lighting.

6. Exchange of experience between the involved in the Project countries.
In collaboration with Sofia Technical University - Science & Research Sector
Research Laboratory for Lighting Equipment

DESIGN STUDY

SITE: SVILOZA VISCOSE RAYON FILAMENT PLANT IN SVISHTOV

SUB-SITE: RECONSTRUCTION OF LIGHTING EQUIPMENT IN THE SORTING AND PACKAGING WORKSHOP

PART: ELECTRICAL

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Senior Research Fellow, DSc Z. Ivanov
MSc B. Toshev

DESIGN TEAM LEADER: Prof. DSc N. Vassilev

PROJECT MANAGER: DSc L. Radulov

Sofia, July 2003

OPET CHP/DHC • Work Package 5 • Task 4
Technical Design Study Report
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3. Lighting estimates

4. Assessment of energy and cost savings resulting from the reconstruction of lighting in the workshop and assessment of greenhouse gases emissions

5. Assessment of the sanitary and ergonomic effect of the reconstruction of the lighting installation

6. Specification

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8. Sources of reference
EXPLANATORY MEMORANDUM

1. Research and analysis of the existing lighting equipment in the Sorting and Packaging Workshop.

As per the original design, the workshop is illuminated by 102 luminaires with 2x80 W luminescent lamps. They are mounted in six rows, as shown in Fig. 1.

In the meantime, changes have been made and the originally installed 80 W lamps have been replaced with 58 W lamps.

The luminaires are obsolete and worn out, due to which their light distribution capacity has deteriorated significantly and their efficiency has been impaired. Due to this, the illuminance values measured in the workshop are significantly lower than the rated and standard values. The attached figure demonstrates the actual illuminance of some of the typical workplaces.

The total rated installed capacity amounts to 19.0536 kW. The annual electricity consumption is 38,412 kWh, out of which “daytime” power represents 24,007 kWh and “peak” power is equal to 14,404 kWh.

Lighting control in the workshop is manual: at the beginning of the working day all luminaires are switched on and the end of the day they are switched off.

The workplaces for quality check of bobbins are illuminated through spot lighting provided by white-day-light luminescent lamps of 2x36 W. The colour rendering index of these lamps fails short of producing sufficiently good rendering of the colour of the bobbins that are subject to quality check. The above-mentioned workplaces have a sufficient degree of illuminance (1000 – 1300 lx). Illuminance in the immediate proximity to the workplaces is low, which results in challenges for the workers to adapt from light to darkness and vice versa. The lamps are connected to the electrical installation through conventional chokes, and as a result significant flicker occurs, although no complaints have been voiced by the workers. The luminaires for general lighting are mounted at 5-m height, and therefore no discomfort glare or any other discomfort occurs.
2. Reconstruction of the lighting installation

2.1. Selection of regulatory illuminance indicators

There are four types of visual tasks performed in the workshop:

- Quality check of bobbins;
- Weighing of bobbins;
- Packaging of bobbins;
- Safe movement of workers on the territory of the workshop.

The most difficult visual task is checking the quality of bobbins. The thread thickness is about 300 – 500 µ. The luminance contrast between the object and the background is very low – the white thread is to be checked against the white background of the bobbin, while the dyed thread is checked against the background of the same-colour bobbin.

To improve the identification of certain defects, the surface of a white bobbin is checked against a black background, and if the bobbin is dark the background is white. In compliance with the existing Bulgarian standards (1), the visual task in both cases should be classified as a first-category task – “the highest degree of precision, with the object to be subject to differentiation smaller than 0.15 mm”. In the former case the luminance contrast is low and the background is light. In such conditions, the recommended illuminance is 3,000 lx for combined lighting and 1,000 lx for general lighting. In the latter case the luminance contrast is high and hence the recommended illuminance is 1,500 lx for combined lighting and 400 lx for general lighting.

In accordance with the European norms for indoor lighting (2), the recommended illuminance of the workplace where such types of tasks are to be performed should be 1,000 lx.

Apparently, there is no fundamental discrepancy between the illuminance values recommended by the Bulgarian standard BDS 1786 and those indicated in the European norms. Taking into account that the European norms are much more recent (2002), as well as the long experience of the Sviloza Viscose Rayon Filament Plant, it is appropriate to ensure illuminance of 1,000 lx.

Along with illuminance, the European norms also recommend a colour-rendering factor $R_a \geq 90$; luminance discomfort factor $UGR \leq 16$ and colour temperature $T_{col} \geq 4,000$ K. All these recommendations are reflected in the attached design.
In the immediate proximity to the above-mentioned working places, as per the European norms, illuminance should be not less than $E = 500$ lx. The same degree of illuminance is required for the workplaces where bobbins are weighed. The uniformity of lighting is 0.6.

In the packaging section of the workshop, horizontal illuminance of $E \geq 300$ lx will be ensured, with uniformity of lighting of 0.3.
In the areas for movement of workers it is necessary to ensure illuminance of $E = 300$ lx.

2.2. Design of the new lighting installation

Thus formulated lighting requirements will be met in the following way:

a) General lighting of the workshop:

It is envisaged that 50 2x58 W luminescent luminaires with alodised aluminium reflectors should be mounted at the height of 3.5 m. The following options have been discussed:

- Open luminaires with IP 23, with electromagnetic chokes and electronic ballast;
- Closed luminaires with transparent Plexiglas (IP 65), with electromagnetic chokes and electronic ballast.

The lamps produce white light ($T_{col} = 4000$ K) and their colour rendering factor is $R_a \geq 80$.

The luminaires are to be mounted in six lines, as shown in Fig. 2.
The power supply for the luminaires in each row will be ensured through a 5x1.5 mm$^2$ main line.

The lighting control is envisaged to remain manual. The lighting will be switched on in the morning before the work starts and switched off after the completion of cleaning.
To reduce electricity consumption, it would be expedient to install a movement sensor. When no people are present in the workshop, the sensor will transmit a signal for switching off the lights.
Luminaires with T12 2 x 36W - 50 at H = 3.5m from the floor

Fig. 2

Working place

Enorms = 1000 lx

Emesure = 1020 lx

Working place

Enorms = 500 lx

Emesure = 533 lx

Working place

Enorms = 300 lx

Emesure = 398 lx
The achieved illuminance is presented in the lighting estimates in the form of isolux curves.

Thus it can be immediately seen that at the workplace for weighing the bobbins illuminance is E ≥ 500 lx, i.e. the regulatory requirements (E_{norm} = 500 lx) are met.

The achieved uniformity is E_{min}/E_{average} = 0.69

In the packaging section of the workshop the illuminance is E = 200–300 lx, again meeting the regulatory requirements.

The luminance discomfort is UGR = 14.6, therefore the regulatory prescriptions are met as well.

**b). Lighting at the workplaces for quality check of bobbins:**

The most demanding visual tasks are performed at the ten workplaces for the end-product quality check.

Under the European norms for indoor lighting, for such tasks the illuminance should be E = 1000 lx. To meet such a requirement, spot luminaires will be installed, with a compact luminescent 55 W Osram - manufactured lamp producing white light T_{col} = 4000 K and with colour rendering factor of R_{a} ≥ 90. Thus precise identification of the colour of bobbins will be ensured.

The luminaires are open and will be mounted on a special post allowing adjustment of the height of the lamp and the direction of the light flow in accordance with individual needs. The reflector of the luminaire should be manufactured from alodised aluminium. The degree of protection is IP 21.

The luminaires are with electronic ballast, thus eliminating any discomfort flicker. If so required, the electronic ballast can be regulated and allow individual dimming of the luminaires at each workplace.
3. Lighting estimates
The nominal values shown in this report are the result of precision calculations, based upon precisely positioned luminaires in a fixed relationship to each other and to the area under examination. In practice the values may vary due to tolerances on luminaires, luminaire positioning, reflection properties and electrical supply.
1. Summary

1.1 Room Summary

<table>
<thead>
<tr>
<th>Room Dimensions</th>
<th>Surface</th>
<th>Reflectance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width 24.00 m</td>
<td>Ceiling</td>
<td>0.70</td>
</tr>
<tr>
<td>Length 36.00 m</td>
<td>Left Wall</td>
<td>0.50</td>
</tr>
<tr>
<td>Height 10.80 m</td>
<td>Right Wall</td>
<td>0.50</td>
</tr>
<tr>
<td>Working Plane Height 0.80 m</td>
<td>Front Wall</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>Back Wall</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>Floor</td>
<td>0.30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Room Position (Front Bottom Left)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X 0.00 m</td>
</tr>
<tr>
<td>Y 0.00 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Average Room Surface Luminance (cd/m²):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>19.1</td>
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</tbody>
</table>

Unified Glare Rating (CIE): Undefined

The overall new value factor used for this project is 1.25.

1.2 Project Luminaires

<table>
<thead>
<tr>
<th>Code</th>
<th>Qty</th>
<th>Luminaire Type</th>
<th>Lamp Type</th>
<th>Power (W)</th>
<th>Flux (lm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>50</td>
<td>TMX400/258 GMX 440</td>
<td>2 * TL-D58W</td>
<td>111.0</td>
<td>2 * 5200</td>
</tr>
<tr>
<td>L</td>
<td>1</td>
<td>FBS506/155</td>
<td>1 * PL-L55W</td>
<td>58.0</td>
<td>1 * 3000</td>
</tr>
</tbody>
</table>

The total installed power: 5.61 (kWatt)

Number of Luminaires Per Arrangement:

<table>
<thead>
<tr>
<th>Arrangement</th>
<th>Luminaire Code</th>
<th>Power (kWatt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line2</td>
<td>E 11 L 0</td>
<td>1.22</td>
</tr>
<tr>
<td>Line3</td>
<td>E 11 L 0</td>
<td>1.22</td>
</tr>
<tr>
<td>Line4</td>
<td>E 11 L 0</td>
<td>1.22</td>
</tr>
<tr>
<td>Line5</td>
<td>E 11 L 0</td>
<td>1.22</td>
</tr>
<tr>
<td>Line6</td>
<td>E 3 L 0</td>
<td>0.33</td>
</tr>
<tr>
<td>Line7</td>
<td>E 3 L 0</td>
<td>0.33</td>
</tr>
<tr>
<td>Individuals</td>
<td>E 0 L 1</td>
<td>0.06</td>
</tr>
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</table>

1.3 Calculation Results

<table>
<thead>
<tr>
<th>(II)Luminance Calculations:</th>
</tr>
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<tr>
<td>Calculation</td>
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<tr>
<td>ALL</td>
</tr>
<tr>
<td>Rabotna plosht</td>
</tr>
<tr>
<td>produkciq za kontrol</td>
</tr>
<tr>
<td>Gotova produkcia</td>
</tr>
<tr>
<td>rabotno miasto</td>
</tr>
</tbody>
</table>
2. Calculation Results

2.1 ALL: Iso Contour

Grid: Grid at Z = 0.80 m
Calculation: Surface Illuminance (lux)
Result Type: Total

<table>
<thead>
<tr>
<th>Grid</th>
<th>Calculation</th>
<th>Result Type</th>
<th>Average</th>
<th>Min/Ave</th>
<th>Min/Max</th>
<th>Project new value factor</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>404</td>
<td>0.19</td>
<td>0.14</td>
<td>1.25</td>
<td>1:250</td>
</tr>
</tbody>
</table>

E  TMX400/258 GMX 440
L  FBS506/155
2.2 ALL: Filled Iso Contour

Grid: Grid at Z = 0.80 m
Calculation: Surface Illuminance (lux)
Result Type: Total

---

**Average**  | **Min/Ave** | **Min/Max** | **Project new value factor** | **Scale**
---|---|---|---|---
404 | 0.19 | 0.14 | 1.25 | 1:250

---

E  | TMX400/258 GMX 440
L  | FBS506/155
3. Luminaire Details

3.1 Project Luminaires

**TMX400/258 GMX 440  2 x TL-D58W / 830**

![Image of luminaire](image1)

Light output ratios

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DLOR</td>
<td>0.77</td>
</tr>
<tr>
<td>ULOR</td>
<td>0.00</td>
</tr>
<tr>
<td>TLOR</td>
<td>0.77</td>
</tr>
</tbody>
</table>

Ballast: Electronic  
Lamp flux: 5200 lm  
Luminaire wattage: 111.0 W  
Measurement code: LVN8794900

Note: This luminaire is a special version of the mentioned measurement code.

**FBS506/155  1 x PL-L55W / 840**

![Image of luminaire](image2)

Light output ratios

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>DLOR</td>
<td>0.61</td>
</tr>
<tr>
<td>ULOR</td>
<td>0.00</td>
</tr>
<tr>
<td>TLOR</td>
<td>0.61</td>
</tr>
</tbody>
</table>

Ballast: Electronic  
Lamp flux: 3000 lm  
Luminaire wattage: 58.0 W  
Measurement code: LVW0822500

Note: This luminaire is a special version of the mentioned measurement code.
4. Installation Data

4.1 Legends

Project Luminaires:

<table>
<thead>
<tr>
<th>Code</th>
<th>Qty</th>
<th>Luminaire Type</th>
<th>Lamp Type</th>
<th>Flux (lm)</th>
</tr>
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<tbody>
<tr>
<td>E</td>
<td>50</td>
<td>TMX400/258 GMX 440</td>
<td>2 * TL-D58W</td>
<td>2 * 5200</td>
</tr>
<tr>
<td>L</td>
<td>1</td>
<td>FBS506/155</td>
<td>1 * PL-L55W</td>
<td>1 * 3000</td>
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</table>

4.2 Luminaire Positioning and Orientation

<table>
<thead>
<tr>
<th>Qty and Code</th>
<th>Position</th>
<th>Aiming Points</th>
<th>Aiming Angles</th>
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<table>
<thead>
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<th>Qty and Code</th>
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<th>Aiming Angles</th>
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CalcuLuX Indoor 4.5b
Philips Lighting B.V.
Page: 6/7
Date: 18-07-2003
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<td>1 * E</td>
<td>22.00</td>
<td>30.80</td>
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</tr>
</tbody>
</table>
4. Assessment of energy and cost savings resulting from the reconstruction of lighting in the workshop and assessment of greenhouse gases emission.

A quantitative estimate has been made based on the rated indicators of the lighting installation:

**The current status:**

- Type of the installed luminaires with electromagnetic ballast 2x80 W
- Number of the luminaires installed 102 pcs.
- Total installed capacity, incl. chokes 19.054 kW
- Annual “peak” energy consumption $W_{a.p.} = 14.40 \text{ MWh}$
- Annual “daytime” energy consumption $W_{a.d.} = 24.01 \text{ MWh}$
- Total annual consumption $W_a = 38.41 \text{ MWh}$
- Annual cost of “peak” energy $A_{a.p.} = \text{BGL 1,757.35}$
- Annual cost of “daytime” energy $A_{a.d.} = \text{BGL 1,632.51}$
- Total annual energy bill $A_a = \text{BGL 3,389.86}$
- Annual emission of greenhouse gases $G = 19 \text{ t.}$
Reconstruction: Option 1

- Type of the installed luminaires with electromagnetic ballast 2x58 W
- Number of installed luminaires 50 pcs.
- Total installed capacity, incl. chokes 6.72 kW
- Annual “peak” energy consumption $W_{a,p} = 5.08$ MWh
- Annual “daytime” energy consumption $W_{a,d} = 8.47$ MWh
- Total annual consumption $W_a = 13.55$ MWh
- Annual cost of “peak” energy $A_{a,p} = BGL 619.80$
- Annual cost of “daytime” energy $A_{a,d} = BGL 575.80$
- Total annual electricity bill $A_a = BGL 1,195.57$
- Annual emission of greenhouse gases $G = 7$ t.
- Investments needed for the replacement of luminaires BGL 1,500
- Payback period 0.8 yr.
Reconstruction: Option 2

- Type of the installed luminaires with electronic ballast 2x58 W
- Number of installed luminaires 50pcs
- Total installed capacity, incl. chokes 5.95 kW
- Annual “peak” energy consumption $W_{a.p.} = 4.50 \text{ MWh}$
- Annual “daytime” energy consumption $W_{a.d.} = 7.50 \text{ MWh}$
- Total annual consumption $W_{a.} = 12.00 \text{ MWh}$
- Annual cost of “peak” energy $A_{a.p.} = \text{BGL 548.78}$
- Annual cost of “daytime” energy $A_{a.d.} = \text{BGL 509.80}$
- Total annual electricity bill $A_{a.} = \text{BGL 1,058.58}$
- Annual emission of greenhouse gases $G = 6 \text{ t.}$
- Investments needed for the replacement of luminaires $\text{BGL 3,000}$
- Payback period 1.20 yr.
### Black Sea Regional Energy Centre

#### Work Package 5 • Task 4

**Technical Design Study Report**

<table>
<thead>
<tr>
<th></th>
<th>Current status</th>
<th>Reconstructed, with control gear</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Installed capacity</td>
<td>Annual electricity consumption</td>
</tr>
<tr>
<td></td>
<td></td>
<td>kW</td>
</tr>
<tr>
<td><strong>Daytime energy</strong></td>
<td>1,260</td>
<td>0.068</td>
</tr>
<tr>
<td><strong>Peak energy</strong></td>
<td>756</td>
<td>0.122</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td>38,412.06</td>
<td>3,389.86</td>
</tr>
</tbody>
</table>

**Annual savings of electricity**
24,864.54 kWh

**Annual savings of electricity cost**
BGL 2,194.30

**Payback period - luminaires with IP 23**
0.80 yr.

**Payback period - luminaires with IP 65**
1.24 yr.

<table>
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<tr>
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<th>Current status</th>
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</tr>
</thead>
<tbody>
<tr>
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<td>3,389.86</td>
</tr>
</tbody>
</table>

**Annual savings of electricity**
26,416.86 kWh

**Annual savings in electricity cost**
BGL 2,331.29

**Payback period - luminaires with IP**
1.20 yr.

**Payback period - luminaires with IP 65**
1.55 yr.
5. **Assessment of the sanitary and ergonomic effect of the reconstruction of the lighting installation**

Lighting has a multifaceted biological impact on the human body, which is outlined in the Fig. 1. This impact of light accounts for activity, efficiency, fatigue and mood.

Fig. 2 demonstrates how increased illuminance impacts the productivity of weavers and, correspondingly, the reduction in the number of manufacturing defects.

Fig. 3 demonstrates the dependence of the number of manufacturing defects on the different in different shifts.

Fig. 4 represents the correlation between the efficiency of workers performing visual tasks and the level of illuminance for medium-challenging visual tasks (left) and highly challenging visual tasks (right). The dotted line represents the data for younger people, while the continuous line relates to older people.

Fig. 5 shows the improvement of human ability to memorise, deduct and calculate rapidly and accurately increases with an increase in luminance from 90 to 500 lx.

These positive effects resulting from improved lighting are difficult to quantify, which leads to the tendency to overlook their importance. Nonetheless, such positive effects are easy to prove and are of special significance when visual tasks are crucial for the manufacturing process, as is the case with the *Sviloža* Viscose Rayon Filament Plant.
Light → Eye

1. Optical part of the visual path
2. Energy part of the visual path

2a. Cerebrum
2b. Adrenal gland
2c. Physiological functions
2d. Activity

Physiological functions:
- Metabolism
- Blood sugar
- Electrolytes
- Lipid exchange
- Protein exchange

Eosinophines:
- Water amount
- Metabolism
- Circulation
- Pulse
- Thyroid gland functions

Mental functions:
- Mood
- Comfort

Fig. 1
Fig. 2 demonstrates how increased illuminance impacts the productivity of weavers and, correspondingly, the reduction in the number of manufacturing defects.
Fig. 3

Fig. 3 demonstrates the dependence of the number of manufacturing defects on the different shifts in different shifts.
Fig. 4 represents the correlation between the efficiency of workers performing visual tasks and the level of illuminance for medium-challenging visual tasks (left) and highly-challenging visual tasks (right). The dotted line represents the data for younger people, while the continuous line relates to older people.
Fig. 5 shows how the human capacity to memorise, deduct and calculate rapidly and accurately increases with an increase in illuminance from 90 lx to 500 lx.
6. SPECIFICATION OF MATERIALS

<table>
<thead>
<tr>
<th></th>
<th>Name and performance of the materials</th>
<th>Measure</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Industrial luminaire with a 2x58 W luminescent lamp with aluminium reflector</td>
<td>pieces</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>Tubular luminescent lamp 58 W – (Φ ≥ 5,400 lm, T&lt;sub&gt;col&lt;/sub&gt; = 4000 K)</td>
<td>pieces</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>Cable 5x1.5 mm&lt;sup&gt;2&lt;/sup&gt;</td>
<td>m</td>
<td>250</td>
</tr>
</tbody>
</table>

7. QUANTITATIVE ESTIMATE

<table>
<thead>
<tr>
<th></th>
<th>Type of works</th>
<th>Measure</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Removal of the existing luminaires with 2x80 W luminescent lamps from the metal fixture</td>
<td>pieces</td>
<td>102</td>
</tr>
<tr>
<td>2</td>
<td>Moving the existing bearing structure of the luminaires from 5 m height to 3.5 m</td>
<td>pieces</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Supply and mounting of a metal fixture for an industrial luminaire with 2x58 W luminescent lamp and aluminium reflector</td>
<td>pieces</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>Laying cables on the metal carrier</td>
<td>m</td>
<td>250</td>
</tr>
</tbody>
</table>
8. Sources of reference:

1. Bulgarian State Standard BDS 1786 – 84 – Natural and artificial lighting

2. European norms for indoor lighting EN 12464 – 1/11.2002