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Reducing the Energy Overheads of a Manufacturing Company

Darina Matisková

Department of Industrial Engineering and Informatics, Technical University of Kosice, Faculty of Manufacturing Technologies with a seat in Presov, Bayerova 1, 08001 Presov, Slovak Republic, darina.matiskova@tuke.sk,

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Abstract : The paper deals with reducing energy costs. Nowadays, with ever-increasing energy prices, it is important for a company to minimize the consumption of all energy. In the course of its activities, the company comes into contact with other entities of different nature. It is connected to this environment by inputs and outputs. Every company has certain goals. A very important group of objectives consists of economic objectives such as achieving profit, ensuring financial stability and liquidity of the company, efficiency of production and other activities.

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1 Introduction

The company can ensure the efficiency of its activities either by maximizing outputs or minimizing inputs or by optimizing the relationship between inputs and outputs. In ensuring the activity of the enterprise and achieving the set objectives, the bulk of inputs are in the form of costs and the bulk of outputs are in the form of revenues. The difference between revenues and costs over a certain period represents the economic result. Overheads are costs at which a lot of money can be saved, including, in particular, the cost of various types of energy [1].

One way to reduce electricity consumption is to replace old lighting with new and modern lighting sources. There are many different options on the market that a company can decide on. They can choose from classic incandescent bulbs to energy-saving fluorescent and halogen lamps to LED light sources. The application of LED lights is important because currently LED lighting is not only equal to any light source, but even achieves better parameters than all available light sources [2]. The world's leading manufacturers, e.g. CREE and OSRAM, already offer light sources that exceed all parameters of existing light sources. LED lights have several advantages:

- reduced cost of electricity
- the light is emitted in one direction only, so there is no reflection loss
- LED luminaires are up to 97% efficient
- under thermal conditions the lifetime is up to 100 000 hours, which is equivalent to 25 years with 10.7 hours of light per day
- energy and CO_2 savings of approximately 50% compared to conventional technologies
- LED working temperature range: from - 30°C to + 60°C
- minimal heat development
- special LED current sources ensure a continuous luminous flux, no stroboscopic effect, no problems with low temperatures, instant start, LED as a semiconductor achieves even better results at lower temperatures than at 25°C/ all LED chip parameters are tested at this temperature /
- LED chips are shock resistant
- spot or area lighting
- LEDs create shadows on the surface of the material, making it easier to detect irregularities
- adjustable from 0 to 100%
- instant start of lighting at 100% power
- free of harmful substances and gases (lead, mercury, heavy metals)
- LEDs do not produce UV radiation

- LED colour temperature is 6000K, which corresponds to daylight
- high specific power = 100 to 137 lm/W
- high protection against water and dust
- the colour rendering index for white is RA=75, this parameter expresses how the human eye can distinguish different colours, the higher this index is, the more colours in the colour spectrum we can detect
- universal supply voltage: 100-250V-60Hz or 24V
- possibility of power supply from photovoltaic panels
- Variability of luminaire dimensions (manufacturers are able to produce LED light in any dimensions according to customer's needs)
- under optimal thermal conditions, the manufacturer guarantees a 16% drop in LED efficiency after 55 000 hours and a 30% drop after 100 000 hours [3].

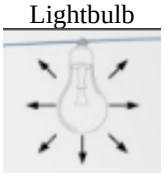
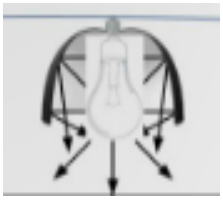
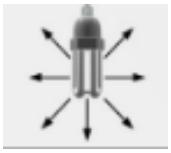
2 Increasing the quality of lighting

The following tables show the major advantages of LED lights compared to other light sources, which include their long lifetime and high luminous efficiency [4].

Table 1 Comparison of light sources

Type of light source	Manufacturer's stated lm/W	Retrievable lm/W	Lifetime (h)
Lightbulb	17	10	3000
Halogen bulb	20	12-20	10000
Tubular fluorescent lamp (neon)	60	40-50	20000
Halogen lamp	65-70	34-40	10000-20000
High pressure sodium discharge lamp	95-110	55-65	24000
Low pressure sodium discharge lamp	120-140	65-75	16000
Power LED-Cree	145	100-137	100000

Table 2 Graphical-mathematical comparison of the luminous efficiency of incandescent, energy-saving and LED lights

Type of light source	Utilisation index	Effectiveness
Lightbulb  17 lm/W	 58 %	10 lm/W
Energy saving bulb  60 lm/W	 58 %	35 lm/W
LED  145 lm/W	 72 – 97 %	100 – 137 lm/W

To improve the quality of lighting and save electricity, we decided to replace two basic types of lighting in the company's working areas:

- main hall lighting in the form of 300W bulbs replaced with LED Industry
- lighting of individual tables of assembly workplaces by replacing neon tubes with LED Leon 30

LED Industry lights were chosen because according to the technical parameters they are suitable for lighting production halls, assembly lines or storage areas. They are designed to cope with higher operating temperatures, they are easy to install by a single-point suspension from the ceiling and the basic beam angle is 60° which will be sufficient to illuminate halls as they are suspended several metres above the floor [5].

Figure 1 Luminaire LED Industry

Table 1 Technical specifications of LED Industry luminaire

Luminous flux	Specific luminous flux	Power	Weight
10 530 lm	81 lm/W	130 W	5,6 kg

According to the technical specifications the LED Industry achieves a luminous flux of 10530 lumens. Currently, 300 watt bulbs with a luminous efficacy of 10 lm/W are used in halls and warehouses, which is equivalent to a luminous flux of 3000 lumens per bulb. A comparison of the luminous fluxes of the individual lights clearly shows that one 130 watt LED Industry luminaire can fully replace three 300 watt bulbs, thus achieving an even higher luminous flux than using three 300 watt bulbs and at a lower power consumption.

We decided to use LED Leon luminaires (Figure 2), which are suitable for illuminating disassembly and assembly tables and also for exit inspection workplaces. Unlike the LED Industry, they have a 120° beam angle and are therefore suitable for illuminating workbenches in assembly, disassembly and inspection workplaces.

Figure 2 Leon LED luminaire

Table 2 Technical specifications of the LED Leon luminaire

Luminaire	Luminous flux	Specific luminous flux	Power	Weight
LED Leon 30	3 480 lm	116 lm/W	33 W	2,9 kg
LED Leon 60	6 960 lm	116 lm/W	66 W	6 kg

Replacing the 58 watt fluorescent tubes currently in use, which have a luminous flux of 2,900 lumens, with the new LED Leon 30 luminaire gives a luminous flux of 3,828 lumens. Replacing this old lighting with the new one will save almost half the electricity, increase the luminous flux and therefore the worker will not strain his eyes in low light.

3 Energy savings and financial payback after replacing the main hall

At the moment, there are 9 bulbs of 300 W with a luminous flux of 27,000 lumens in each of the production halls. In total, these bulbs consume 2 700 W per hour. The following table (Table 5) shows the energy consumption of the old and new lights:

Table 5 Comparison of old and new lighting in one hall

Type of light	Number of lights	Power consumption per 1 light [Wh]	Total energy consumption [Wh]	Luminous flux [lm]
Light bulb	9	300	2 700	27 000
LED Industry	3	130	390	31 590
Hourly energy saving is **2 310 Wh**				

After replacing the old bulbs with new LED lights, the luminous flux increased from the original 27000 lumens to 31590 lumens and the electricity consumption decreased from 2700 Wh to 320 Wh. The replacement of the lighting consumes 2310 Wh less electricity, which is 85.5% of the original consumption, while the luminous flux increased by 17%. Calculating this over all three halls (Table 6), the hourly energy saving is 6930 watts.

Table 6 Comparison of old and new lighting in all halls

Type of light	Number of lights	Power consumption per 1 light [Wh]	Total energy consumption [Wh]	Luminous flux [lm]
Light bulb	27	300	8 100	81 000
LED Industry	9	130	1 170	94 770
Hourly energy saving is **6 930 Wh**				

The company is currently working eight-hour shifts, with only one shift in the two dismantling and repair halls and two shifts in the assembly line hall where workers assemble the calipers. The following table (Table 7) shows how much energy can be saved in one working day.

Table 7 Energy savings per working day

	Light bulb	LED Industry
2 halls (dismantling + repair)		
number of lights	18	6
energy consumption per 1 hour	5,4 kWh	0,78 kWh
power consumption in 8 hours	43,2 kWh	6,24 kWh
energy saving	43,2 – 6,24 = **39,96 kWh**	
1 hall (assembly)		
number of lights	9	3
energy consumption per 1 hour	2,7 kWh	0,39 kWh
power consumption in 16 hours	43,2 kWh	6,24 kWh
energy saving	43,2 – 6,24 = **39,96 kWh**	
energy savings per 1 working day	39,96 + 39,96 = **79,92 kWh**	

By analogy we can calculate the energy savings for one working month (Table 8), if we take into account that a month has 31 days and no work on weekends, so a month has 23 working days.

Table 8 Average monthly savings after replacing hall lighting

	Light bulb	LED Industry
	savings in single-shift operation	
Number of lights	18+9	6+3
Energy consumption per 1 hour	8,1 kWh	1,17 kWh
Energy consumption per 1 day (8 hours)	64,8 kWh	9,36 kWh
Energy consumption for 1 month (23 days)	1 490,4 kWh	215,28 kWh
Energy savings in 1 month	1 490,4 – 215,28 = 1 275,12 kWh	
	savings in two-shift operation	
Energy savings in 1 month	1 275,12 x 2 = 2 550,24 kWh	
	savings in three-shift operation	
Energy savings in 1 month	1 275,12 x 3 = 3 825,36 kWh	
	savings with simultaneous operation	
Number of lights	18+9	6+3
Energy consumption per 1 day	86,4 kWh	12,48 kWh
Energy consumption for 1 month (23 days)	1 987,2 kWh	287,04 kWh
Energy savings in 1 month	1 987,2 – 287,04 = 1 700,16 kWh	

The monthly electricity savings can also be quantified in money terms (Table 9). From the last invoice issued for € 2 272 for 14 356 kWh, we find that the electricity supplier charges the company € 0,16 per 1 kWh:

Table 9 Monthly electricity savings in kWh and €

	Savings in kWh	Savings in €
Month of single-shift operation	1 275,12 kWh	204,02 €
Month of two-shift operation	2 550,24 kWh	408,04 €
Month of three-shift operation	3 825,36 kWh	612,05 €
Month at the current changes	1 700,16 kWh	272,03 €

The purchase price of one LED Industry luminaire is 980 €. The cost of replacing the entire hall lighting is therefore € 8 820. The payback period (Table 10) of the invested funds depends on how the production will continue. Calculated on the basis of 250 working days per year, the payback periods are as follows, depending on the number of shifts per day:

Table 10 Payback period for invested funds for the replacement of hall lighting

Single shift operation	
Daily saving	55,44 kWh x 0,16 € = 8,87 €
Annual savings	8,87 x 250 = 2 217,5 €
Payback period in years	8 820 € : 2 217,5 € = 3,98 = **4 years**
Two-shift operation	
Daily saving	2 x 55,44 kWh x 0,16 € = 17,74 €
Annual savings	17,74 € x 250 = 4 435 €
Payback period in years	8 820 € : 4 435 € = 1,98 = **2 years**
Three-shift operation	
Daily saving	3 x 55,44 kWh x 0,16 € = 26,61 €
Annual savings	26,61 € x 250 = 6 652,5 €
Payback period in years	8 820 € : 10 167,5 € = **1,33 years = 1 year and 4 months**
Current type of operation	
Daily saving	73,92 kWh x 0,16 € = 11,83 €
Annual savings	11,83 € x 250 = 2 957,5 €
Payback period in years	8 820 € : 2 957,5 € = 2,98 = **3 years**

It is clear from the above calculations that the acquisition cost of the lights will be recovered from the company the sooner the more shifts are made during the day. Once that payback period is exceeded, these lights can earn us money for other designs that can be applied. For example, if we consider a two-shift operation, the lights have a lifetime of 25 years when lit for 16 hours a day (100 000 h : (250 x 16 h)). The payback period for a two-shift operation is 2 years, which when subtracted from the lifetime, gives us 23 years, during which the company saves 102,005 euros (23 years x 4,435 euros) on electricity. In single-shift operation, the lights have a lifetime of 50 years and, after deducting the payback period, the saving is 102 005 euros. Similarly, for three-shift operation, the lifetime is 16.6 years and the saving then amounts to EUR 101 584.

4 Energy savings and payback after workplace lighting replacement

Each workbench, whether for disassembly, repair or assembly, is illuminated by a 58 W tubular fluorescent lamp. A total of 5 disassembly tables, two repair tables and 12 tables are currently in use on the assembly line. In total there are 19 lights, to which we can add another 7 lights, which are located in two warehouses where in one warehouse we will replace two old lights with two new lights and in the other warehouse we will replace 5 old lights with 4 new LED Leon 30 lights. So we replace these 26 lights with 25 LED Leon 30 type luminaires. After the replacement we get an hourly saving (Table 11) with a higher luminous flux value.

Table 11 Hourly savings with LED Leon 30

Type of light	Number of lights	Power consumption per 1 light [Wh]	Total energy consumption [Wh]	Luminous flux [lm]
Tubular fluorescent lamp	26	58	1 508	60 320
LED Leon 30	25	33	825	95 700
Hourly energy saving is 683 Wh				

The hourly saving with the new lights is 683 Wh, which translates into a 45.29% saving in electricity costs. The following table (Table 12) calculates the hourly electricity savings with the changes as they are in the current state of operation:

Table 12 Hourly energy savings with lights LED Leon 30

	Tubular fluorescent lamp	LED Leon 30
2 halls (dismantling + repair)		
number of lights	7	7
energy consumption per 1 hour	406 Wh	231 Wh
power consumption in 8 hours	3,25 kWh	1,85 kWh
energy saving	3,25 – 1,85 = 1,4 kWh	
1 hall (assembly)		
number of lights	12	12
energy consumption per 1 hour	696 Wh	396 Wh
power consumption in 16 hours	11,14 kWh	6,34 kWh
energy saving	11,14 – 6,34 = 4,8 kWh	
warehouses		
number of lights	7	6
energy consumption per 1 hour	406 Wh	198 Wh
power consumption in 16 hours	6,5 kWh	3,3 kWh
energy saving	6,5 – 3,3 = 3,2 kWh	
energy savings per 1 working day	1,4 + 4,8 + 3,2 = 9,4 kWh	

After calculating the hourly savings, as with the hall lighting, we can calculate the monthly savings (Table 13) when using LED lights Leon 30:

Table 13 Monthly savings with Leon 30 LED lights in kWh and €

	Tubular fluorescent lamp	LED Leon 30
	savings in single-shift operation	
Number of lights	26	25
Energy consumption per 1 hour	1508 Wh	825 Wh
Energy consumption per 1 day (8 hours)	12,06 kWh	6,6 kWh
Energy consumption for 1 month (23 days)	277,38 kWh	151,8 kWh
Energy savings in 1 month	277,38 – 151,8 = **125,58 kWh**	
Savings per 1 month in euros	125,58 kWh x 0,16 € = **20,1 €**	
	savings in two-shift operation	
Energy savings in 1 month	125,58 kWh x 2 = **251,16 kWh**	
Savings per 1 month in euros	251,16 kWh x 0,16 € = **40,2 €**	
	savings in three-shift operation	
Energy savings in 1 month	125,58 kWh x 3 = **376,74 kWh**	
Savings per 1 month in euros	376,74 kWh x 0,16 € = **60,2 €**	
	savings with simultaneous operation	
Energy consumption per 1 day	20,89 kWh	11,49 kWh
Energy consumption for 1 month (23 days)	480,47 kWh	264,27 kWh
Energy savings in 1 month	480,47 – 264,27 = **216,2 kWh**	
Savings per 1 month in euros	216,2 kWh x 0,16 € = **34,6 €**	

The price of one Leon 30 LED luminaire is 303 €. The initial investment for the purchase of all lights is 7 575 €. In the table (Table 14) the individual payback periods after replacement of the installed LED Leon 30 lights are calculated.

Table 14 Payback period for investment with LED lights Leon 30

Single shift operation	
Daily saving	5,46 kWh x 0,16 € = 0,87 €
Annual savings	0,87 x 250 = 217,5 €
Payback period in years	7 575 € : 217,5 € = **34,8 years**
Two-shift operation	
Daily saving	2 x 5,46 kWh x 0,16 € = 1,74 €
Annual savings	1,74 € x 250 = 435 €
Payback period in years	7 575 € : 435 € = **17,4 years**
Three-shift operation	
Daily saving	3 x 5,46 kWh x 0,16 € = 2,62 €
Annual savings	2,62 € x 250 = 655 €
Payback period in years	7 575 € : 655 € = **11,6 years**
Current type of operation	
Daily saving	9,4 kWh x 0,16 € = 1,5 €
Annual savings	1,5 € x 250 = 375 €
Payback period in years	7 575 € : 375 € = **20,2 years**

5 Conclusion

It is clear from the above calculations that the acquisition cost of the lights will be recouped by the company the sooner the more changes take place during the day. Once that payback period is exceeded, these lights can earn us other designs that can be applied. For example, if we consider a two-shift operation, the lights when lit 16 hours a day have a lifetime of 25 years (100 000 h : (250 x 16 h)). The payback period for a two-shift operation is 17.4 years, which, when subtracted from the lifetime, gives 7.6 years, during which the company saves 3 306 euros (7.6 years x 435 euros) in electricity. In single-shift operation, the lights have a lifetime of 50 years and after subtracting the payback period, the saving comes out to 3 306 euros. Similarly, for three-shift operation, the lifetime is 16.6 years and the saving then amounts to EUR 3 275.

As electricity prices are currently rising steadily, it is very likely that the savings over these years of the LED lights' lifespan may increase even further. In addition to these potential savings over these years, we can also add those savings that would otherwise have to be spent on buying bulbs with a much shorter lifetime. Also, during this period, unnecessary waste is not produced and the environment is thus also protected.

Quality lighting improves work well-being and ultimately productivity.

6 The reference list

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