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Energy Audit of an Enterprise from Machine Industry

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Abstract: An energy survey of an enterprise operating in field of machine industry is carried out. During the energy audit, primary information about energy consumed by the enterprise for heating, ventilation, lighting and needs of production process for three year period was collected. Annual energy costs for three consecutive years were compared and highest energy costs were taken as a basis for determining the energy consumption baseline. Proposals for energy-saving measures are defined. The specific energy costs before and after energy-saving measures were calculated and comparisons between them were made. An assessment to optimize number of workers in the enterprise and increase its competitiveness was made. The effect of increasing the productivity of the enterprise was evaluated. Direct and indirect cost savings were estimated, realized during the implementation of energy-saving measures. Annual energy savings in machine industry enterprise as energy saved in kWh/year and in saved carbon emissions/year to the environment were presented.

Keywords: Energy survey, Energy audit, Energy efficiency, Carbon emissions

Introduction

Subject to mandatory energy efficiency audit in accordance with regulation act in Bulgaria are: large enterprises for the production of goods, large service providers, industrial systems whose annual energy consumption is over 3000 MWh (Ordinance №E-RD-04-3, 2016), (Ordinance №E-RD-04-05, 2016). However, in addition to them, many large and small businesses also take advantage of the opportunities of energy auditing to expand their production and implementation of new energy-efficient technological lines (Ivanov et al., 2021; Kamburova et al., 2017; Iliev et al., 2013). The main goals they want to achieve with this are the following:

- achieving low energy costs of the enterprise. The new technological equipment consumes less energy, which leads to a reduction in the specific energy costs per unit. Realized energy savings achieved help reduce the term of repayment for energy-saving measures and realizing greater profits from their implementation (Baev et al.,2015), (Kaloyanov et al, 2020);
- achieving reduction of operating costs in the enterprise. Use of highly efficient technological lines leads to a reduction in costs for repairs, consumables, blanks, etc. Expenses for employee business trips and for paying for services to subcontractors are also reduced;
- increasing the production capacity without increasing the workforce of the enterprise This leads to increased labor productivity, reduced technological waste due to human errors, both in terms of carbon emissions in the environment and technological waste;

- increasing the degree of automation in the production process. Reducing human errors in the production process leads to the production of a high-quality product in a continuous process. The increased level of automation of technological lines makes it easy to monitor energy consumption in real time;
- increasing the level of competence of the staff. The presence of automated technological lines in the enterprise leads to the fact that the enterprise will employ a small number of people, but each of them will have a high level of competence. The presence of highly competent personnel such as engineers, technologists, etc. guarantees the production of high quality products;
- production of products that meet current standards in the European Union. This requires the use of high-quality raw materials and highly efficient technologies in the production process. Under these conditions, the high quality of the product and the sale of the company's products on European markets are guaranteed;
- production of new products. In many cases, the purchased highly efficient technological lines have the ability to produce new products, which allows the company to increase both its productivity and its assortment. By covering a high standard of quality of all manufactured products, the company opens up opportunities to sell its product on new markets;
- low levels of harmful emissions to the environment. During the production of the product, low levels of harmful emissions into the atmosphere must be guaranteed, both from the equipment operating in the enterprise itself and from the sources producing energy that is subsequently supplied to the enterprise.

The presence of highly efficient technological lines and highly qualified personnel in the enterprise creates prerequisites for the company to easily implement and maintain quality standards in its production. In this way, the enterprise can create its own methodologies for waste management, for energy management, which are coordinated and comply with local legislation. Maintaining an enterprise resource planning (ERP) system is additional evidence of the high level of quality of the products produced. All of this is important for the enterprise to be able to participate in interaction with other enterprises for the conditions of circular economy.
Assessment of the need and effectiveness of energy-saving measures in an enterprise is carried out with the help of energy audit (Kreith & Goswami, 2007; Rasheva, 2011; Shapiro, 2016; Thuman & Younger, 2008; Turner, 1997).

Method

The object of the present survey for energy efficiency of an industrial system is a machine enterprise in Bulgaria. The enterprise produces components for electric lamps and lighting fixtures. The following technological processes in process are carried out:

- Milling operation on details;
- Drilling operation on details;
- Manual operation - chamfering, plating and assembly on details.

Detailed energy analysis of the enterprises includes:

- collection of primary information on the energy costs of the enterprise for a period of 3 consecutive years and analysis in order to determine the potential for energy savings;
- determination of a reference year, on the basis of which the baseline of energy consumption of the enterprise is determined;
- determination of specific energy consumption depending on the production in the enterprise;
- determining the amount of energy savings as saved energy and as saved carbon emissions to the environment.

The introduction of energy-saving measures in the enterprise, such as the supply of new energy-efficient equipment, should not conflict with the requirements for:

- reducing the amount of waste from the enterprise;
- recycling materials used in production process;
- circular economy.

Results and Discussion

In Table 1 are shown data on installed electrical power of the facilities in the enterprise.

Table 1. Installed electrical power of the facilities in the enterprise

Name	Value	Power, kW	Total power, kW
Lathe with CNC	3	15.36	46.08
Horizontal processing center with CNC	1	27.00	27.00
Lathe universal	1	7.30	7.30
Universal milling cutter	1	7.30	7.30
Milling cutter	1	4.25	4.25
Watchmakers lathe	1	0.22	0.22
Hydraulic hacksaw machine	1	1.25	1.25
Hydraulic hacksaw machine	1	1.65	1.65
Drilling machine	3	1.30	3.90
Compressor for compressed air Working pressure 6 atm	1	1.50	1.50
Compressor for compressed air Working pressure 6 atm	1	1.00	1.00
Total usable power			101.45

In Table 2 are shown data for annual consumption of electrical energy in enterprise for 2021, 2022 and 2023 year.

Table 2. Annual consumption of electrical energy in enterprise for 2021, 2022 and 2023 year

Year	2021	2022	2023
Month	kWh	kWh	kWh
January	4566	4899	5304
February	4850	4340	4578
March	4620	4300	4306
April	5001	5025	5224
May	4200	3930	3873
June	4003	4880	4951
July	4685	4780	4793
August	3895	4222	4545
September	3768	3955	4160
October	3688	3554	4116
November	4935	3333	5066
December	4555	4892	4336
Total	52766	52110	55252

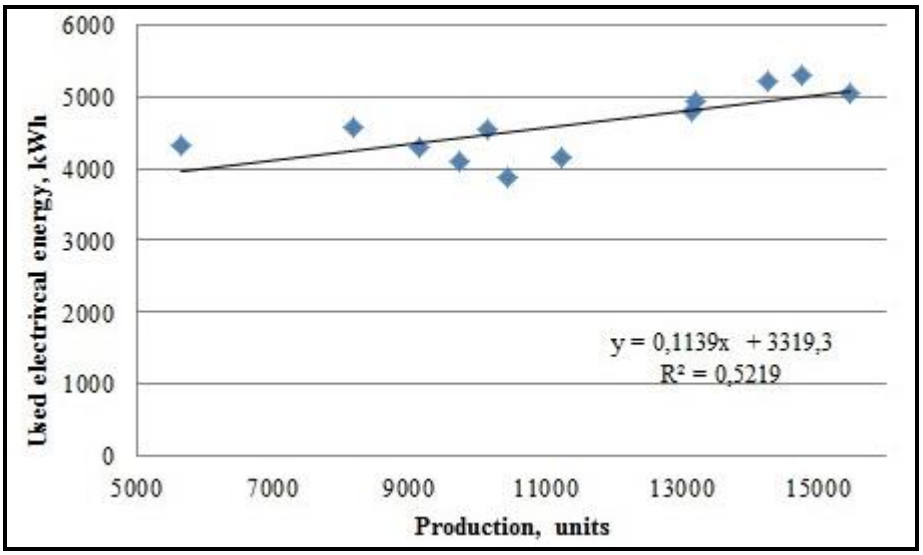

Figure 1. Correlation between used energy in enterprise and number of manufactured unit.

Used electrical energy is reported for production period of three years 2021, 2022 and 2023. Data in table show that annual consumption of electrical energy in enterprise is higher for 2023 year.. This is why this year was chosen as a reference year for energy audit. On Figure 1 are shown correlation between used energy in enterprise and number of manufactured unit. On Figure 2 is shown percentage distribution of electrical energy consumed in enterprise for reference year.

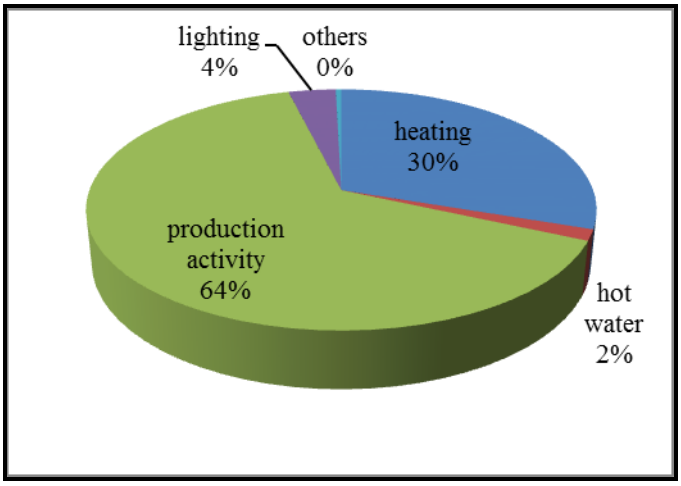

Figure 2. Percentage distribution of energy consumed in enterprise for reference year

The graph shows that there is a great potential for saving energy in machines with which the production activity is carried out. This requires optimization and replacement of facilities consuming electrical energy for production activity. The enterprise intends to make the following investments:

- Vertical processing center with CNC – 1 pieces (existing horizontal processing center will also be used in production process);
- Strip cutting machine - 1 pieces (new equipment - will replace two hydraulic hacksaw machine);
- Anodizing line– 1 pieces (new equipment);
- Spray dyeing line - 1 pieces (new equipment);

In Table 3 are shown data on installed electrical power of facilities in enterprise after energy saving measures. The installation of the new equipment will lead to an increase in the amount of new finished products from the enterprise. Data for the baseline of energy consumption in the enterprise after energy saving measures are shown in a Table 4.

Table 3. Installed electrical power of facilities in enterprise after energy saving measures.

Name	Value	Power, kW	Total power, kW
Lathe with CNC	3	15.36	46.08
Horizontal processing center with CNC	1	27.00	27.00
Vertical processing center with CNC	1	11.00	11.00
Lathe universal	1	7.30	7.30
Universal milling cutter	1	7.30	7.30
Milling cutter	1	4.25	4.25
Watchmakers lathe	1	0.22	0.22
Drilling machine	3	1.30	3.90
Strip cutting machine	1	1.19	1.19
Anodizing line	1	40.00	40.00
Spray dyeing line	1	60.00	60.00
Compressor for compressed air Working pressure 6 atm	1	1.50	1.50
Compressor for compressed air Working pressure 6 atm	1	1.00	1.00
Total usable power			210.74

Table 4. Baseline of energy consumption in the enterprise after energy saving measures

Name	Value	Unit of measure
Power consumption horizontal processing center with CNC - old	8876	kWh/year
Quantity produced before energy saving measures	10575	Units/ year
Power consumption processing center with CNC – old+new	18366	kWh/year
Quantity produced after energy saving measures old	26025	Units/ year
Power consumption hydraulic hacksaw machines	1075	kWh/year
Quantity produced before energy saving measures	12912	Units/ year
Power consumption strip cutting machine	413	kWh/year
Quantity produced after energy saving measures	19110	Units/ year
Power consumption anodizing line machine – good practice	43610	kWh/year
Quantity produced before energy saving measures	72000	Units/ year
Power consumption anodizing line machine – new	36960	kWh/year
Quantity produced after energy saving measures	72000	Units/ year
Power consumption spray dyeing line machine – good practice	28864	kWh/year
Quantity produced before energy saving measures	29400	Units/ year
Power consumption spray dyeing line machine – new	25099	kWh/year
Quantity produced after energy saving measures	29400	Units/ year
Baseline power consumption	95895	kWh/year

The implementation of a new horizontal processing center with CNC, strip cutting machine, anodizing line machine and dyeing line machine are accordingly marked as energy-saving measures ESM 1, ESM 2, ESM 3 and ESM 4. A comparison of specific costs before and after energy saving measures is shown in Table 5.

Table 5. Comparison of specific costs before and after energy saving measures

	Before ESM				After ESM		
	Energy consumption for related with measures activities	Produced output	Specific energy consumption	Corrected energy consumption for related with measures activities	Energy consumption for related with measures activities	Produced output	Specific energy consumption
	kWh/year	Units/year	kWh/unit	kWh/year	kWh/year	Units/year	kWh/unit
ESM 1	8876	10575	0.839	21835	18366	26025	0.706
ESM 2	1075	12912	0.083	1586	413	19110	0.022
ESM 3	43610	72000	0.606	43610	36960	72000	0.513
ESM 4	28864	29400	0.982	28864	25099	29400	0.854
Total:	82425	-	-	95895	80838	-	-

The share of the enterprise's energy savings compared to the reference year 2019 has been determined in energy value (in kWh) and ecological equivalent (t CO_2/ year). The results are shown in Table 6.

Table 6. Energy savings

Energy saving measures	Energy carrier	Energy savings		Ecological equivalent
		kWh	%	t CO_2/ year
ESM 1	electricity	3469	15.89	2.8
ESM 2	electricity	1173	73.96	1.0
ESM 3	electricity	6650	15.25	5.4
ESM 4	electricity	3765	13.04	3.1
Total:	-	15057	15.70	12.3

Conclusion

With the introduction of the energy-saving measures, additional benefits will be realized, as follows:
ESM 1 - with implementation of new vertical processing center productivity and quality of the products will increase. Production interruptions in event of technical failures and needs for repair work will be avoided;
ESM 2 - with the implementation of strip cutting machine, savings will be achieved on ongoing operating costs, achieving savings on the loss of cutting material (waste reduction is expected up to 3 times, which will reduce the cost of purchasing materials for production);
ESM 3 - with the implementation of anodizing line machine savings will be generated from costs to a subcontractor company for performing service, fuel costs, travel expenses and remuneration of a seconded employee, carrying out the transport of the details to a subcontractor company;
ESM 4 - with the implementation of dyeing line machine savings will be generated from costs to a subcontractor company for performing service, fuel costs, travel expenses and remuneration of a seconded employee, carrying out the transport of the details to a subcontractor company;

No new personnel are expected to be hired to service new anodizing and dyeing line machines, as after implementation of new processing center, the company's existing employees will be able to perform maintenance activities on this machines. Upon implementation of the energy-saving measure, object of investment intention, the enterprise will realize an energy saving of 15.70% compared to the baseline of energy consumption, which is equal to an energy saving of 15057 kWh/ year with an ecological equivalent of 12.3 tons of CO_2 emissions saved.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM Journal belongs to the authors.

Acknowledgements or Notes

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