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Energy Saving Measures in Enterprise from Canning Industry

Slav Valchev
University of Food Technology

Stanislava Tasheva
University Of Food Technology

Ana Semerdzhieva
University of Food Technology

Abstract: An energy survey of an enterprise from the canning industry was carried out. This survey includes: collection of primary information on the energy costs of the enterprise for a period of three 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 separated carbon emissions to the environment. The baseline for energy consumption is determined, depending on the energy consumption in the enterprise for the considered period of the survey. The specific costs for energy carriers in the enterprise were calculated, and on this basis an economic and ecological assessment of the proposed energy-saving measures was carried out. A regression equation was derived to determine the energy consumption depending on the processed output of an industrial system.

Keywords: Energy audit, Energy survey, Saved carbon emissions

Introduction

Energy in industry plays an important role in determining the price of manufactured products. In addition, energy consumption largely determines its quality. 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). Improving energy efficiency of enterprise has one of the following two objectives:

- while preserving the production result, to ensure lower costs of energy resources for enterprise or
- while maintaining the costs of energy resources for the enterprise to increase its production result.

In both cases, as a result of introduced energy-saving measures in enterprise, we ensure reduction of specific energy consumption per unit of manufactured product (Baev et al.,2015; Kaloyanov et al, 2020). Industrial systems are also subject to an energy audit one year after major changes have been made to technological equipment and/or production systems, changing the fuel base and the way energy is converted (Ivanov et al., 2021; Kamburova et al., 2017; Iliev et al., 2013; Berk, 2009; Fellows, 2000; Balentas et al., 1997; Brennan, 2006).

Method

The object of the present survey for energy efficiency of an industrial system is a canning enterprise in Bulgaria. The enterprise specializes in processing seasonal fruits and vegetables, mainly for export to European countries. It processes about 2,000 tons of different fruits and vegetables per season. The product range also includes a variety of canned products from fruits, vegetables, ready meals, sauces and jams. In enterprise for canning industry the following technological processes are carried out:

- Technological lines for processing peaches;
- Filling and closing section;
- Equipment for pasteurization and sterilization;
- Equipment for the production of compote from cherries, sour cherries, prunes and apricots;
- Equipment for the production of roasted pepper;
- Equipment for the production of tomatoes with salty-sour topping or tomato juice topping;
- Preparation of tomato juice for topping;

The choice of energy-saving measures, guaranteeing highest value energy savings in form of energy and carbon emissions released into the environment, requires a detailed energy analysis of enterprise's energy costs This analysis 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 potential for energy savings;
- determination of a reference year, on the basis of which baseline of energy consumption of enterprise is determined;
- determination of specific energy consumption depending on production in enterprise;
- determining amount of energy savings as saved energy and as saved carbon emissions to the environment.

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

- reducing amount of waste from enterprise (includes management of production storage processes, monitoring expiration dates of food products, use of artificial intelligence to predict future consumption of food products) ;
- recycling materials used in production process (using food waste to obtain innovative food products and bio fuels for needs of enterprise);
- using innovative biodegradable materials for product packaging (switching to biodegradable or recycled packaging in order to reduce plastic waste from enterprise);
- circular agriculture (integrating livestock and crop production can also create a balanced ecosystem, reducing need for chemical fertilizers and pesticides used in growing vegetables).

The energy survey used data provided by the owner of the enterprise and the engineering team that developed the technological project for reconstruction, as well as technical catalogs for technological equipment.

Results and Discussion

The energy carriers used for enterprise needs are natural gas and electricity. The factory is fully gasified. Natural gas is used to obtain process steam. Steam is used for pasteurization and sterilization of finished products. Electricity is used to power the production machines and equipment, as well as for lighting. The available electrical power of the company is 250 kW. A 200 kVA diesel generator is used for emergencies. In Table 1 are shown data on installed electrical power of the facilities in the enterprise. The annual consumption of electricity for needs of the technological process and produced output before energy savings measures are presented in Table 2. Process steam is used for needs of the pasteurization tunnels and autoclaves. It is obtained from a steam boiler with a productivity of 4000 kg steam/hour. The burner of steam boiler use natural gas. Annual consumption of electrical energy of enterprise for 2017, 2018 and 2019 year are presented in Table 2. In Table 3 are shown data for annual consumption of natural gas in enterprise for 2017, 2018 and 2019 year.

Used energy (electrical and natural gas) is reported for production period of three years 2017, 2018 and 2019. Data in table show that the total energy consumption are the highest for 2019 year. This is why this year was chosen as a reference year for energy audit. Using this data the baseline for energy consumption of the enterprise is determined. On Figure 1 is shown percentage distribution of energy consumed in enterprise for 2019 year.

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

Name	Value	Power, kW	Total power, kW
Pallet turning machine	1	2.0	2.0
Fan washing machine	1	3.7	3.7
Inspection line	1	1.1	1.1
Calibrator for whole peaches	1	1.5	1.5
Conveying belt	1	0.6	0.6
Elevator	1	2.0	2.0
Bone grafting machine	10	0.56	5.6
Inspection line	1	0.8	0.8
Conveying belt	1	0.6	0.6
Inspection line	1	0.8	0.8
Elevator	1	3.0	3.0
Reception tub with pressure pump	2	4.0	8.0
Buffer tank	1	4.0	4.0
El. motor	1	2.2	2.2
El. motor	1	2.2	2.2
Conveyor belts	5	0.56	2.8
Rotating tables	6	0.55	3.3
Filling tables	3	4.5	13.5
Conveyor belt (full jars)	2	0.75	1.5
Distribution belt	3	0.57	1.7
Metal box stopper	1	7.5	7.5
Tunnel - pasteurizing	1	18.0	18.0
Compressor	1	15.0	15.0
Boiler pump	1	5.5	5.5
Burner	1	9.7	9.7
Lighting	150	2x0.058	17.4
Total usable power			133.7

Table 2. Annual consumption of electrical energy of enterprise for 2017, 2018 and 2019 year

Year	2017	2018	2019
Month	kWh	kWh	kWh
January	7746	3878	5228
February	7214	6454	3791
March	8041	7449	3550
April	5922	6668	3518
May	6801	7868	2815
June	13580	5459	8311
July	24450	16210	24710
August	39065	28004	37215
September	1235	1146	17142
October	1461	2210	13683
November	2551	2884	9653
December	3064	3470	9079
Total	121130	91700	138695

Table 3. Annual consumption of natural gas for enterprise for 2017, 2018 and 2019 year

Year	2017	2018	2019
Month	kWh	kWh	kWh
January	0	0	0
February	0	0	0
March	0	0	0
April	0	0	0
May	9207	7306	0
June	140567	135761	137350
July	266536	270628	298292
August	519158	540031	600975
September	0	200147	220713
October	0	88225	101961

November	0	0	0
December	0	0	0
Total	935468	1242098	1359291

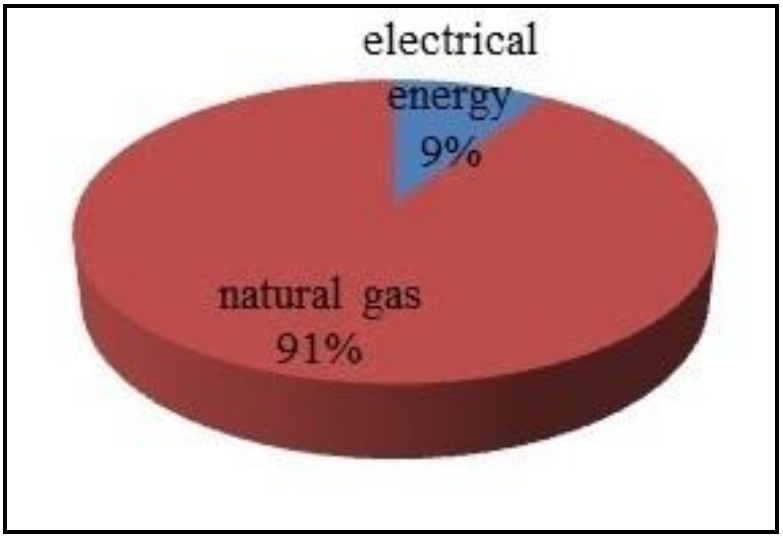

Figure 1. Percentage distribution of energy consumed by enterprise 2019 year

The graph shows that there is a great potential for saving energy in enterprise in optimization and replacement of facilities consuming fuel - natural gas. Annual consumption of electricity for needs of the technological process and produced output before energy saving measures are presented in Table 4. Annual energy cost for autoclaves, steam pasteurizing tunnel and roasting peppers before energy saving measures are presented in Table 5.

Table 4. Annual consumption of electricity for needs of the technological process and produced output before energy saving measures

Name	Value	Unit of measure
Total usable power	133.7	kW
Consumed electrical energy	138695	kWh/year
Hours of equipment operation	1037.36	hours/year
Produced output	3629182	units/year
Production capacity of technological line	3498	units/hour
Specific energy consumption	0.038	kWh/unit

Table 5. Annual energy cost for autoclaves, steam pasteurizing tunnel and roasting peppers before energy saving measures

Name	Value	Unit of measure
Autoclaves		
Steam consumption	220	kg/ hour
Autoclave	7	cycle/day
Total autoclaves (10 pcs.)	2200	kg/ hour
Total autoclaves (10 pcs.)	70	cycle/day
Packs per cycle	500	units
Total autoclaves (10 pcs.)	35000	units/day
Total autoclaves (10 pcs.)	17600	kg/ day
Number of packages processed	1957188	unit/year
Operation of autoclaves	55.9	days
Used steam autoclaves	983.8	t/year
Used heat energy autoclaves	619819	kWh/year
Specific energy consumption	0.317	kWh/unit
Pasteurization tunnel		
Steam consumption	1600	kg/ hour
Pasteurization tunnel capacity	3000	units/hour
Number of packages - boxes	1671994	units
Operation of pasteurizing tunnel	557.3	hours

Used steam pasteurizing tunnel	851.7	t/year
Used heat energy pasteurizing tunnel	536558	kWh/year
Specific energy consumption	0.321	kWh/unit
Roasting peppers		
Energy for roasting peppers	79303	kWh/year
Annual cost		
Total steam consumption	1835.5	t/year
Natural gas energy consumption	1359291	kWh/year
Specific energy consumption natural gas	741	kWh/t steam

In Table 6 are shown data for specific energy consumption of final product for 2017, 2018 and 2019 year.

Table 6. Specific energy consumption for final product 2017, 2018 and 2019 year

Year		2017	2018	2019
Manufactured product	Unit/ year	2554401	3299545	3629182
Consumed electrical energy	kWh/ year	121130	91700	138695
Specific electricity consumption	kWh/ unit	0.047	0.028	0.038
Consumed natural gas	kWh/ year	935468	1242098	1359291
Specific natural gas consumption	kWh/ unit	0.366	0.376	0.385
Consumed electrical + natural gas energy	kWh/ year	1056598	1333798	1497986
Specific energy consumption for final product	kWh/ unit	0.414	0.404	0.424

The enterprise intends to make the following investments:

- Peach pitting machines – 3 pieces;
- Bottling machine by level - 3 pieces;
- Monobloc – 1 piece;
- Automatic machine for closing and orienting caps - 1 piece;
- Linear rinser - 1 piece;
- Automatic flotation machine - 1 piece;
- Sealing machine for metal cylindrical boxes - 3 pieces;
- Compressor installation - 1 piece;
- Gas forklift - 1 piece;
- Electric car – 3 pieces;
- Automatic titrator - 1 piece;
- System for weight control of products in rigid packaging – 4 pieces;
- Peach elevator tub - 3 pieces;
- Inspection tape, roll - 1 piece;
- Transport road feeding pasteurization tunnel - 1 piece;
- Pasteurization tunnel-cooler for cans 1 kg -1 piece;
- Buffer table - 1 piece;
- Aerial transport line for empty metal cans (1kg) - 1 piece;
- Reconstruction of a boiler plant installation of a second boiler 2.5 t/h - 1 piece;

The delivery of the new equipment will lead to an increase in production at the enterprise. This necessitates the determination of adjusted baseline energy consumption for new higher amount of output produced. The data are shown in Table 7.

Table 7. Baseline of enterprise according to new produced output

Name	Value	Unit of measure
Produced output according to the plan of enterprise	5740000	Unit/ year
Specific electricity consumption 2019	0.038	kWh/ unit
Specific natural gas consumption 2019	0.385	kWh/ unit
Baseline electrical energy consumption	218120	kWh/year
Baseline natural gas energy consumption	2209900	kWh/year
Total energy consumption by baseline	2428020	kWh/year

In Table 8 are shown data on installed electrical power of facilities in enterprise after energy saving measures.

Table 8. Installed electrical power of facilities in enterprise after energy saving measures

Name	Value	Power, kW	Total power, kW
Pallet turning machine	1	2.0	2.0
Fan washing machine	1	1.1	1.1
Inspection tape - roll type	1	1.1	1.1
Calibrator for whole peaches - 3+2 classes	1	1.0	1.0
Conveyor belt - distributed	1	0.55	0.55
Elevator with water bath	3	0.8	2.4
Peach pitting machine	3	8.0	24.0
Inspection tape - collection	1	0.55	0.55
Conveyor belt - feeding	1	0.55	0.55
Elevator - feeder	1	1.1	1.1
Elevator - feeder	1	1.1	1.1
Conveyor belt - distributed	1	0.55	0.55
"cup up" pitting machine	2	1.5	3.0
Inspection tape	1	0.55	0.55
Inspection tape	1	0.55	0.55
Inspection tape - collection	1	0.55	0.55
Elevator - feeder	1	0.75	0.75
Conveying belt	1	0.55	0.55
"cup down" peach orienteering track	1	1.5	1.5
Installation for thermochemical peeling	1	5.0	5.0
Reception tub with pressure pump	1	3.0	3.0
Water transport road - circulation	1	22.0	22.0
Calibrator for peach halves - 3+2 classes	1	2.2	2.2
Conveyor belt - distributed	1	0.55	0.55
Elevator	3	1.1	3.3
Trasina "cup up" - 3 pcs. Trasina "cup down" - 3 pcs.	6	1.5	9.0
Inspection tape	6	0.55	3.3
Jar feeding station	1	2.0	2.0
Transport route for empty jars	1	1.5	1.5
Linear rinser	1	11.5	11.5
Filling table for products in metal boxes - paired	1	2.2	2.2
Filling table for products in metal boxes	1	1.5	1.5
Filling table for products in glass jars	1	2.2	2.2
Transport road - single	3	0.75	2.25
Conveyor track for boxes	1	0.75	0.75
Transport route for jars	1	0.75	0.75
Transport route for jars	1	0.75	0.75
Weight control system	4	0.25	1.0
Vacuum filling machine	3	0.75	2.25
Bruiser type filling machine	1	0.75	0.75
Transport road	3	0.75	2.25
Sealing machine for metal cans	3	3.0	9.0
Feed elevator for caps	2	0.75	1.5
Sealing machine for jars	1	0.75	0.75
Filling and closing monobloc for glass jars	1	1.5	1.5
Transport route for jars	1	0.75	0.75
Packaging printer	4	0.75	3.0
Transport road	1	0.75	0.75
Set with printer	1	0.35	0.35
Stacking machine. The machine automatically packs ready cans in shrink wrap.	1	26.0	26.0
Tunnel pasteurizer	1	18.0	18.0
Accepted transport route	1	0.75	0.75
Labeling machine	1	2.2	2.2
Transport road feeding pasteurization tunnel.	1	33.0	33.0

Pasteurization tunnel-cooler for cans. Set with outgoing transport path. Water cooling tower and buffer table. Overhead conveyor line for metal boxes			
Transport road	1	0.75	0.75
Set with printer	1	0.35	0.35
Stacking machine. The machine automatically packs ready cans in shrink wrap.	1	26.0	26.0
Compressor equipment. Compressed air compressor. Complete with a microfilter.	1	9.0	9.0
Compressor	1	15.0	15.0
Forklift. Engine fuel type - gas. Load capacity-3 t.	1	0.0	0.0
Electric car. Load capacity - 1.5 t.	3	0.0	0.0
Automatic titrator. Intended for use in the food industry.	1	0.5	0.5
Lighting	150	2x0.058	17.4
Lighting new warehouses	58	2x0.054	6.26
Total usable power			152.0

In Table 9 are shown data on consumed electrical energy in enterprise after energy saving measures. Consumption of natural gas for the needs of pasteurization tunnels is presented in Table 10. Consumption of natural gas for the needs of autoclaves after energy saving measures is presented in Table 11.

Table 9. Consumed electrical energy after energy-saving measures

Name	Value	Unit of measure
Total usable power	kW	152.0
Production capacity of the new line	Unit/hour	5000
Production plan of the enterprise after energy-saving measures	Unit/year	5740000
Hours of operation on new equipment	Hour/year	1148
Consumed electrical energy after energy-saving measures	kWh/year	174496

Table 10. Consumption of natural gas pasteurization tunnels

Name	Value	Unit of measure
Pasteurization tunnel – new line		
Steam consumption	2200	Kg/ hour
Pasteurization tunnel capacity	5000	Unit/ hour
Number of packages	3650000	Unit/ year
Operation of the pasteurizing tunnel - new	730	Hour/ year
Used steam pasteurizing tunnel	1606	t/ year
Used thermal energy pasteurizing tunnel	1011780	kWh/year
Specific energy consumption	0.277	kWh/unit
Pasteurization tunnel – existing		
Steam consumption	1600	Kg / hour
Pasteurization tunnel capacity	3000	Unit/ hour
Number of packages	1120000	Unit/ year
Operation of the pasteurizing tunnel - existing	373.33	Hour/ year
Used steam pasteurizing tunnel	597.33	t/ year
Used thermal energy pasteurizing tunnel	376320	kWh/year
Specific energy consumption	0.336	kWh/unit
Annual cost		
Number of packages	4770000	Unit/ year
Used steam pasteurizing tunnels	1327.33	t/ year
Used thermal energy pasteurizing tunnels	1388100	kWh/year
Specific energy consumption	0.291	kWh/unit

Table 11. Consumption of natural gas for the needs of autoclaves after energy saving measures

Name	Value	Unit of measure
Autoclave	220	Kg steam/ hour
Autoclave	7	Cycles/day
Total autoclaves (10 pcs.)	2200	Kg steam/ hour
Total autoclaves (10 pcs.)	70	Cycles/day
Packs per cycle	500	units
Total autoclaves (10 pcs.)	35000	units/day
Total autoclaves (10 pcs.)	17600	Kg steam/ hour
Number of packages processed	970000	Units/ year
Operation of the autoclaves	27.7	days
Used steam autoclaves	487.8	t steam/ year
Used heat energy autoclaves	307296	kWh/year

The distribution of natural gas energy after energy saving measures is shown in Table 12. The summary analysis energy costs of enterprise after the introduction of the energy saving measure is shown in Table 13.

Table 12. Distribution of natural gas after energy saving measures

Name	Value	Unit of measure
Production plan of the enterprise after energy-saving measures	Unit/year	5740000
Used steam pasteurizing tunnel – new line	1606	t/ year
Used thermal energy pasteurizing tunnel – new line	1011780	kWh/year
Used steam tunnel pasteurizer - existing	597.33	t/ year
Used thermal energy pasteurizing tunnel - existing	376320	kWh/year
Used steam autoclaves	487.8	t/ year
Used heat energy autoclaves	307296	kWh/year
Total steam	2691.13	t/ year
Total steam energy	1695396	kWh/year
Energy /natural gas/ for roasting peppers	79303	kWh/year
Disposal in an integrated economizer	50862	kWh/year
Thermal efficiency of a boiler	95	%
Heat losses in a boiler	84770	kWh/year
Necessary amount of natural gas	1808607	kWh/year
Specific energy consumption (natural gas)	672	kWh/t steam
Specific energy consumption (natural gas)	0.315	kWh/unit

Table 13. Analysis energy costs of enterprise after energy saving measures

Name	Value	Unit of measure
Quantity produced after energy saving measures	5740000	Units/ year
Baseline electrical energy consumption	218120	kWh/year
Baseline natural gas energy consumption	2209900	kWh/year
Total energy consumption by baseline	2428020	kWh/year
Consumed electrical energy after energy saving measures	174496	kWh/year
Energy consumed from natural gas after energy saving measures	1808607	kWh/year
Total required energy after energy saving measures	1983103	kWh/year
Electical energy savings	43624	kWh/year
Natural gas energy savings	401293	kWh/year
Overall energy savings	452020	kWh/year
Specific energy saving /electical energy/	0.008	kWh/unit
Specific energy savings /natural gas/	0.070	kWh/unit
Total specific energy savings	0.078	kWh/unit
Specific electrical energy consumption after energy saving measures	0.030	kWh/unit
Specific consumption of energy from natural gas after energy saving measures	0.315	kWh/unit
Total specific energy expenditure after energy saving measures	0.345	kWh/unit

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 14.

Table 14. Energy savings

Energy saving measures	Energy carrier	Energy savings		Ecological equivalent
		kWh	%	t CO_2/ year
Modernization of a canning enterprise	electricity	43624	19.83	35.4
	natural gas	401293	18.16	81.1
Total:		444557	18.31	116.5

Conclusion

Upon implementation of energy saving measures, the enterprise will realize an energy saving of 18.31% compared to the baseline of energy consumption, which is equal to an energy saving of 444557 kWh/ year with an ecological equivalent of 116.5 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.

Conflict of Interest

* The authors declare that they have no conflicts of interest

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Author Information

Slav Valchev
University of Food Technology
Plovdiv, 26 Maritza Boulevard, Bulgaria,
Contact e-mail: *slavvalchev@uft-plovdiv.bg*

Stanislava Tasheva
University of Food Technology
Plovdiv, 26 Maritza Boulevard, Bulgaria,

Ana Semerdzhieva
University of Food Technology
Plovdiv, 26 Maritza Boulevard, Bulgaria,

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