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Minimization of Heat Energy Intensity in Food Production Companies Applying Sustainable Industrial Development Methods

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Lithuanian food and drink sector of industry is characterized by high energy intensity, which is 29% higher than the EU average. At the confectionary plant chosen for the experiment, an environmental impact has been controlled and its maximum managed by creating different procedures to reduce pollution. Assessment of the plant's environmental costs has revealed that the energy costs amount to main part of the environmental ones (up to 55.4%). In recent years several energy efficiency projects have been implemented allowing minimizing the plant's energy intensity up to 15%.

An algorithm of feasibility analysis of increasing thermal energy efficiency of the plant was suggested which could also be applied to other food industry plants. Demand for heat energy within the plant was evaluated for each technological process; the fuel and energy balance of the plant boiler-house was drawn up. It was revealed that huge heat energy losses were made during heat energy production and usage. During the research period a control system of significant environmental aspects was suggested, its objective function was estimated. Several environmental alternatives were suggested for optimization of the heat energy production processes. Three projects were chosen for the feasibility analysis. Results of technical, economic and environmental evaluations of Cleaner Production (CP) innovations as well as conclusions made are presented in this article.

Key words: *energy efficiency, energy intensity, food industry, environmental performance, environmental indicators, material and energy balance, sustainable industrial development.*

1. Introduction

According to the data of the Department of Statistics of the Government of the Republic of Lithuania, Food, Beverage & Tobacco industry generates the greatest value added (VA) among Lithuanian manufacturing industries (greater than 24%). In 2010 the GDP of Lithuanian Food, Beverage & Tobacco industry comprises 3.6% of the country's GDP. The export of this industry makes about 35% of the manufactured production and about 7% of the country's export (Index data base). In 2009 manufacturing industry consumed 18% of the country's final energy. This consumption increases every year. In recent years energy intensity has downward tendencies, i.e. it has decreased by 9.5%.

Although all over Europe energy intensity increases, but there are still many manufacturing industry plants in which obsolete technologies and worn out equipment are used resulting in great energy losses during energy production, supply and usage. All of these factors decrease energy efficiency and increase environmental impact, cost-prices of production reducing work efficiency.

EU countries are obliged to reduce energy intensity and environmental impact during production of energy, respectively, namely, (European Environment State and Outlook Report 2010): until 2020 to reduce the greenhouse gas emissions by 20%; to dissociate usage of recourses from the economic growth.

Another important document is the EU Directive 2006/32/EC on energy end-use efficiency and energy resources, which proposes to increase the energy end-use efficiency that would reduce the primary energy consumption, CO_2 and other greenhouse gas emissions. The implementation of any measures increasing energy efficiency allows reducing dependence on the energy import (Directive 2006/32/EC).

Research object: food industry enterprises in Lithuania.

An experiment was carried out in the confectionery plant which produces over 50% of Lithuanian confectionery (further - *pilot plant*).

The objective of this research was to evaluate possibilities of heat energy production efficiency by applying cleaner production (CP) preventive methods to food production plants.

To achieve the objective the following tasks have been taken:

- To evaluate the final energy intensity in Lithuania and in Lithuanian food industry and to estimate the objectives for increasing the energy efficiency;
- To analyze the possibilities of implementing CP preventive methods in food industry;
- To suggest an algorithm of feasibility analysis of increasing heat energy efficiency and to apply this algorithm to the pilot plant.

Investigation results are presented in this article.

2. Energy intensity and its reduction possibilities

Currently, efficient consumption of final energy is one of the most relevant objectives of sustainable development of the EU energetic sector.

Until 2000, structural changes in Lithuanian economy, implementation of new technologies, and other measures to increase energy efficiency determine reduction in initial and final energy in the country. Since 2001, the primary and final energy consumption has started to grow slightly together with the growth of the country's economy. Since 2009, consumption of final energy has decreased because of the economic crisis in the country. 17.8% of the final energy was used in the industrial sector (see Table 1).

The energy consumption has a close relationship with the country's GDP, but there is no linear dependence. The energy consumption is growing much more slowly than the GDP due to installation of energy efficiency measures, especially in manufacturing industrial and energy sectors (see Paragraph 3). For this reason the energy intensity indicator is used for evaluation and comparison of the energy efficiency on a world scale and in a country or in a separate sector of the economy. Recently, the energy intensity indicator is widely used to evaluate energy efficiency at the production plant and particular technological process level (Staniškis et al. 2008).

In 2009 oil products comprised main part of final energy consumption in Lithuania (33.3%), 20% - natural gas consumption, 17.2 % - heat energy consumption, 14% - electricity (see Fig. 1).

Table 1. Final energy dynamics of Lithuania's operators for 1995-2009, thousand tons of oil equivalent (toe) toe/year (Index data base)

	1995	2000	2006	2007	2008	2009
Total:	4594	3749	4766	5013	4902	4409
Agriculture	204	99	114	120	117	105
Industry	971	741	1003	1009	897	784
Construction	49	41	53	56	58	38
Transport	1039	1056	1551	1842	1848	1506
Services	691	470	616	633	604	599
Household	1640	1341	1429	1353	1378	1377

Analysis of final energy intensity according to the separate manufacturing branches shows that energy intensity of food companies satisfied the average volume of energy intensity in Lithuanian manufacturing industry, but it is 29% higher than in EU countries (see Fig. 2): in the EU - 0.131 thousand t/EUR, in Lithuania – 0.169 thousand t/EUR. Therefore, we can conclude that energy saving opportunities in Lithuanian food industry are 358.9 thousand t/year (or 498.4 M. nm^3/year of natural gas).

The final energy structure of Lithuanian Food, Beverage & Tobacco industry is presented in Fig.3. Up to 90% of the used final heat energy is produced in their own boiler houses (in 2005 - 88.5%, in 2009 - 89.92%). Up to 80% of the used heat energy is produced by burning natural gas. A similar tendency prevails in the EU Food, Beverage & Tobacco industry. Therefore, we can conclude that an increase in the efficiency of energy production in boiler houses is a relevant issue of food industrial plants, too.

Due to ever high consumption of natural gas, it is necessary to appeal to the strategy of sustainable development and to promote Lithuanian Food, Beverages and Tobacco industry to implement energy efficiency innovations, to acquire new technologies with purpose to reduce energy intensity and environment impact.

Table 2. Final energy use intensity variation in Lithuania, 1995-2009, thousand toe/Lt GDP (Index data base)

	1995	2000	2006	200 7	2008	2009
Total:	0,122	0,082	0,067	0064	0,060	0,064
Agriculture	0,060	0,038	0,043	0,041	0,038	0,034
Industry	0,104	0,077	0,059	0,057	0,050	0,051
Construction	0,017	0,017	0,010	0,009	0,009	0,010
Transport	0,028	0,023	0,022	0,023	0,023	0,022
Services	0,032	0,022	0,020	0,019	0,017	0,020
Household	0,044	0,029	0,020	0,017	0,017	0,020

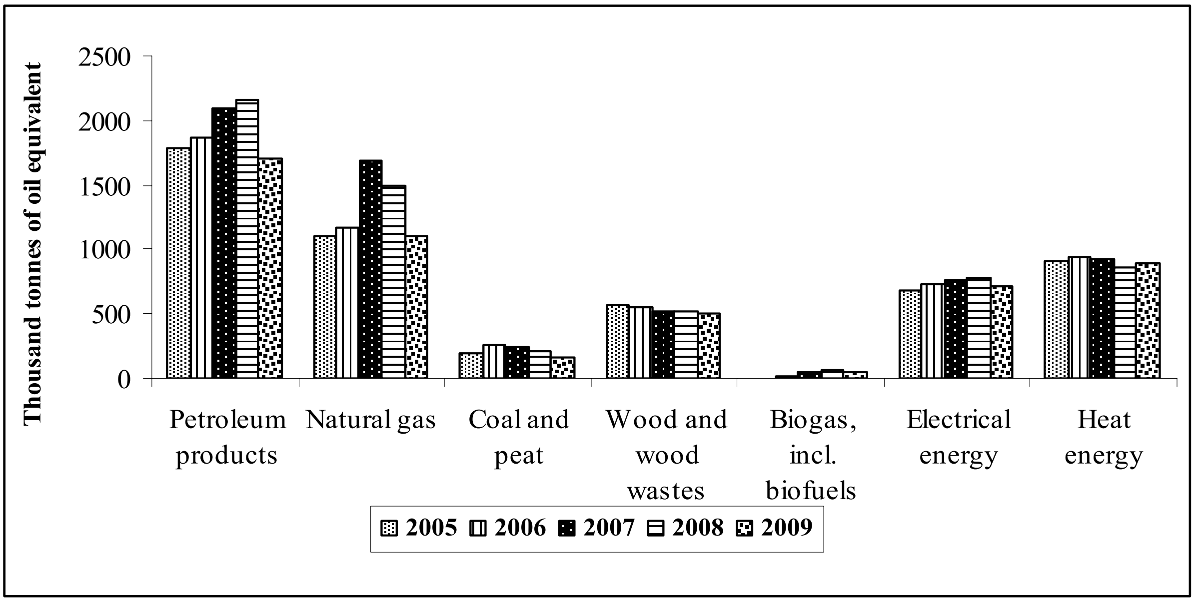

Fig. 1. Structure of final energy consumption in Lithuania, 2005-2009, thousand toe /year

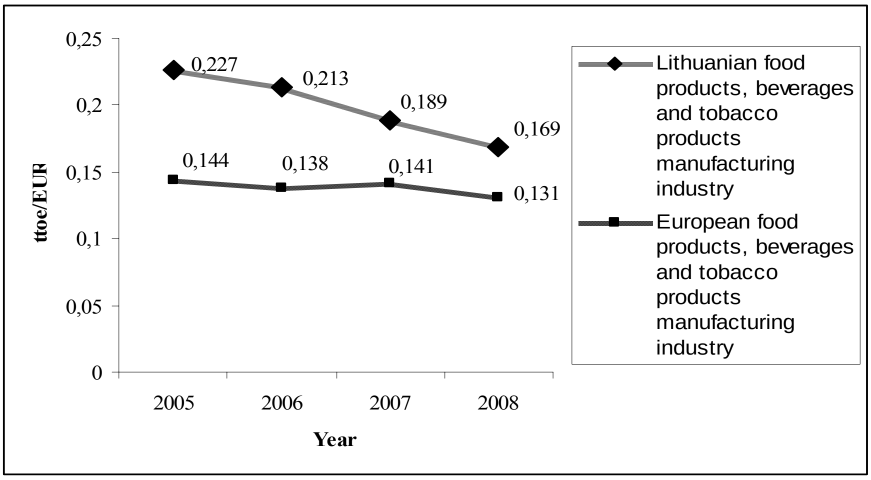

Fig. 2. Variation of final energy intensity in the Food, Beverage & Tobacco industry in the EU and Lithuania, 2005-2008, thousand toe /EUR

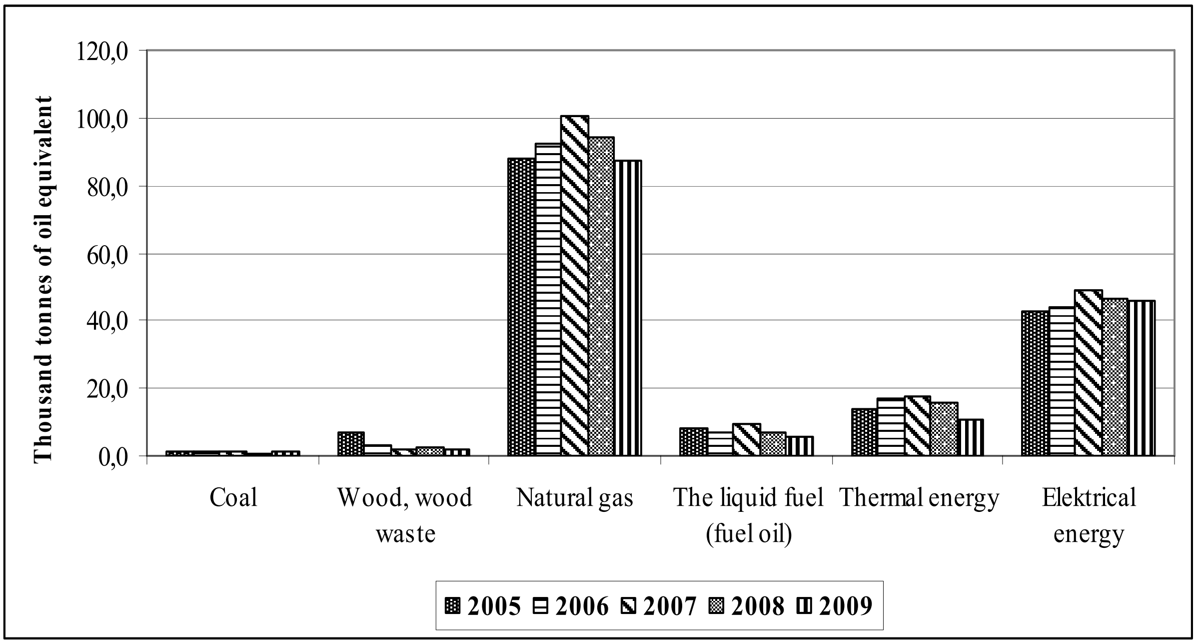

Fig.3. Variation and structure of final energy used in Lithuanian Food, Beverage & Tobacco industry, 2005-2009, thousand toe /year

3. Increase in energy efficiency of Lithuanian food industry by CP methods

Main methods of increasing energy efficiency in food and drink production processes according the EU BAT ID reference documents are as follows (BAT in the Food, Drink and Milk Industries 2006, BAT for energy efficiency 2008):

– Cogeneration of heat and electricity production in new or modernized installations;

– Optimization of energy production systems (optimization of combustion processes; periodical supervision of combustion plants; steam production replacement by heat energy production; implementation of condensate heat recovery system; preheating of feeding water; condensate recycling, steam leak avoidance during condensate recycling; etc.);

– Optimization of energy supply system (optimal layout of energy supply lines; pipelines insulation; periodical supervision of steam lines, e.g. by ultrasonic steam leak detectors; etc.);

– Optimization of energy consumption (installation of control systems; pipelines insulation (minimization of heat energy losses during materials or products transportation, supply, storage and processing processes); waste energy usage by various technical devices (heat pumps, heat exchangers, etc.); optimization of lighting system; implementation of electric motors' frequency changing drives; implementation of CIP systems in washing processes; optimization of cooling production and supplying systems; etc.).

In Lithuania, implementation of CP projects becomes a most efficient way of solving environmental problems, inc. inefficiency of energy production and consumption. The above mentioned methods of increasing energy efficiency in Lithuanian production companies have already been applied since 1994 (Kliopova 2002).

Twenty eight CP innovations were implemented in 14 food and drink production companies while participating in various CP programs, which were organized to industrialists by the KTU Institute of Environmental Engineering (APINI). In the companies that allow minimizing direct processes costs by 1.9 M. EUR/year, up to 60% of the total investment (1.74 M. EUR) was directed to optimization of production processes and improvement of technologies. To implement these innovations the companies got NEFCO's (Nordic Environment Financial Corporation) credits for CP investments on favorable terms (Kliopova 2002, Staniškis et al. 2010).

The implementation of CP innovations allowed minimizing final energy consumption (Staniškis et al. 2010) of:

– electricity – by 1672 MWh/year;
– heat energy – by 10 630 MWh/year;
– fuel oil – by 400 t/year;
– natural gas – by 840 thousand nm^3/year;
– coal – by 564 t/year;
– diesel fuel – by 310 t/year.

Decision of environmental problems is a multi-criteria goal of the optimization of production processes (Kliopova 2002). The result of the analysis of implemented innovations shows that the best environmental and economic achievements have proved to be the implementation of the innovations in which a few CP prevention methods were simultaneously applied.

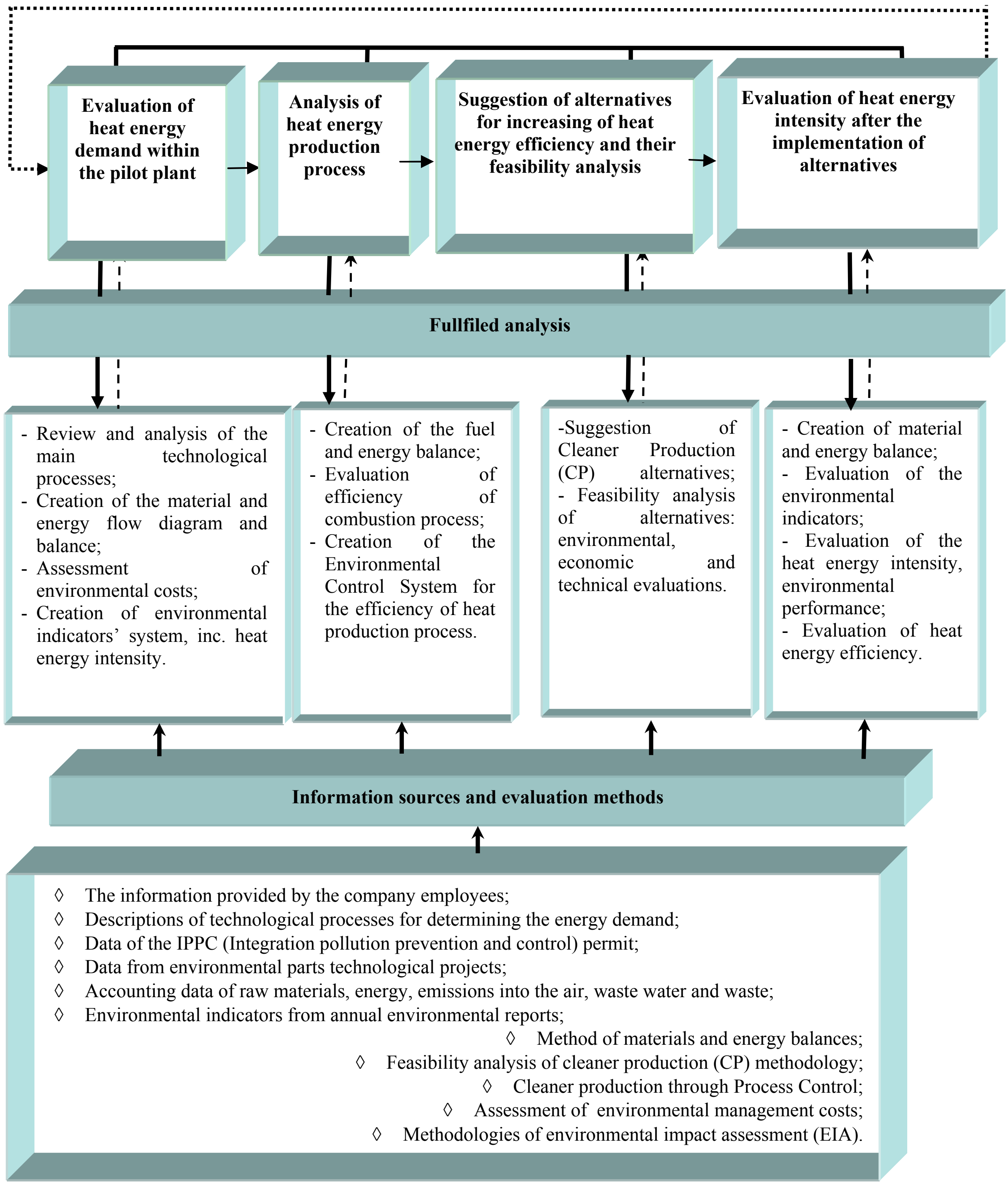

Fig. 4. Algorithm of feasibility analysis of possibilities to increase heat energy efficiency in industrial companies

4. Methodology of evaluation of possibilities to increase heat energy efficiency

We have suggested the algorithm of evaluation of the possibilities to increase heat energy efficiency within the pilot plant. The algorithm could be applied to any industrial company which has its own boiler house.

The main stages of the methodology are: determination of the heat energy demand, analysis of the energy production processes (in the case of energy production in its own boiler-house), supply of alternatives to improve heat energy efficiency and their feasibility analysis; evaluation of heat energy intensity after the implementation of CP alternatives and comparison to the initial intensity before introduction of CP. Industrial sustainable development methods have been used in setting up the following algorithm(Fig. 4).

5. Reduction of heat energy intensity in the pilot plant

Possibilities of reducing energy intensity in the pilot company were assessed applying the above given algorithm (see Fig. 4).

The company produces about 16 thousand t/year of production: 2.8 t of chocolate, 5.4 t of nougat candy, 7.8 t of loose candy. Heat energy (steam) is produced in its own boiler-house (2 steam boilers of the total capacity 6.54 MW), burning natural gas (approx. 2.4 M. nm^3/year). Heat energy intensity in the pilot plant is 1.23 MWh/t of manufactured production. The efficiency of boiler houses is only 85-86%. Thus, heat energy losses during the production amount to 3 000 MWh/year.

Applying the methodology of assessment of environmental management costs [Stasiškienė, 2001, Staniškis J.K., Stasiškienė Ž., Jasch Ch. 2005] it has been ascertained that the energy costs make main part of the environmental costs of production (up to 55.4%).

The plant's materials and energy balance and the fuel and energy balance of the heat energy production process were drawn up with purpose to identify significant environmental aspects:

- high heat energy intensity: 1.23 MWh/t of manufactured production;
- heat energy losses during its production: 0.19 MWh/t of manufactured production;
- gas emissions (CO, NO_x, CO_2), burning natural gas: 0.29 t/t of manufactured production;
- high volume of electricity consumption: 1.18 MWh/t of manufactured production;
- water consumption: 6.63 m^3/t of manufactured production.

The demand for heat energy within the pilot plant was evaluated:

- in technological processes – about 16 thousand MWh/year;
- for heating the premises – about 3 thousand MWh/year;
- for hot water production – about 0.7 thousand MWh/year.

A few energy efficiency projects have been implemented in the plant during the last 5 years: renovation of water circulation system; automation of air conditioning system, plant's cooling system; modernization of heat supply system by renovation of pipelines; renovation of steam/water heat exchanger; renovation of electricity supply system in production departments; reconstruction of administrative department; replacement of circulation pumps by new ones. The implementation of these innovations allowed reducing up to 15% of the energy consumption intensity within the plant. Therefore further research was oriented only to the optimization of the heat energy production process in stem boilers.

During the research period a control system of significant environmental aspects has been introduced to the company and its objective function has been estimated (see Fig. 5). The plant's steam production process is the object of the control system (Kliopova, Staniškis, 2004).

The main analyzing parameters – state variables of that system (**$X_{out}(t)$**) or significant environmental aspects are:

– $X_{out}(t)_1$ - water consumption, m^3/MWh of produced heat energy;
– $X_{out}(t)_2$ - natural gas consumption, nm^3/MWh of produced heat energy;
– $X_{out}(t)_3$ - gas emissions, t/MWh of produced heat energy.

Quality terms of these parameters before CP innovations are presented in Table 3.

Control targets or limitations (X_{in}) are estimated for each parameter of the control system in the pilot plant:

- $X_{in}(t)_1 \leq 1.5$ m^3/MWh,
- $X_{in}(t)_2 \leq 115$ nm^3/MWh,
- $X_{in}(t)_3 \leq 0.225$ t/MWh.

Possible disturbances d(t) affecting an object, are as follows: automatic equipment failure, temperature changes, trouble in the air, electricity or fuel supply; alteration of an air excess coefficient, etc.

The main objective function of the system was estimated:

$W = \mathbf{\Delta X} \rightarrow 0$.

Several environmental alternatives were proposed for optimization of the pilot plant heat energy production process:

1. Continuous check of natural gas supply pipeline and its periodic reconstruction;
2. Automatic control system of natural gas pressure;
3. Condensate recycling to steam-boilers;
4. Modernization of burners of steam-boilers;
5. Implementation of low NOx burners;
6. Implementation of the automatic control system of air excess coefficient (λ);
7. Use of waste energy from exhaust gases (implementation of condensing economizer);
8. Renovation of pumps of the whole heating system;
9. Insulation of pipelines of heating station and equipment;
10. Implementation of the automatic control system of exhaust gases;
11. Replacement of old steam-boilers by new generation ones possessing better energetic characteristics.

After primary evaluation done together with the company's technical specialists, three alternatives were selected for the CP feasibility analysis.

5.1 Results of the feasibility analysis of implementing condensing economizer

During an inventory of stationary sources of the gas emissions, it was found that the temperature of exhaust gases from the boiler–house was higher than 170^0C. Thus, a large volume of heat energy is emitted into the air. In accordance with the requirements, the temperature of the exhaust gases can be higher by 10-20^{0}C than that of the dew point (Marcinauskas K., Korsakienė I. 2006).

The composition of natural gas, density of all components and their low calorific values were used in calculating the volume and mass of exhaust gases inc. water vapors, burning 2.4 M. nm^3 /year of natural gas, when the air excess coefficient is 1.2. It was estimated that the temperature of the dew point for our object was 56.33^{0}C. To maintain the optimal operation of condensing economizer, the temperature of cooling water has to be lower than that of the dew point, in case of our pilot – plant – 40^{0}C (the temperature of recycled thermal water).

Having implemented a condensing economizer, the efficiency of the burning process will increase by 8.59 %. Thus 2.2 M. nm^3 /year of natural gas will be used for producing the same volume of heat energy in the plant (19.65 thousand MWh/year).

The implementation of condensing economizer will allow:

- to minimize natural gas consumption by 219 thousand nm^3/year (or approx. 9% of total natural gas consumption within the plant),
- to decrease gas emissions – by 420 t/year (inc. CO_2),
- to increase electricity consumption by 5.4 MWh/year (due to installation of the recycling pump).

Total CP investments are 145.6 thousand EUR.

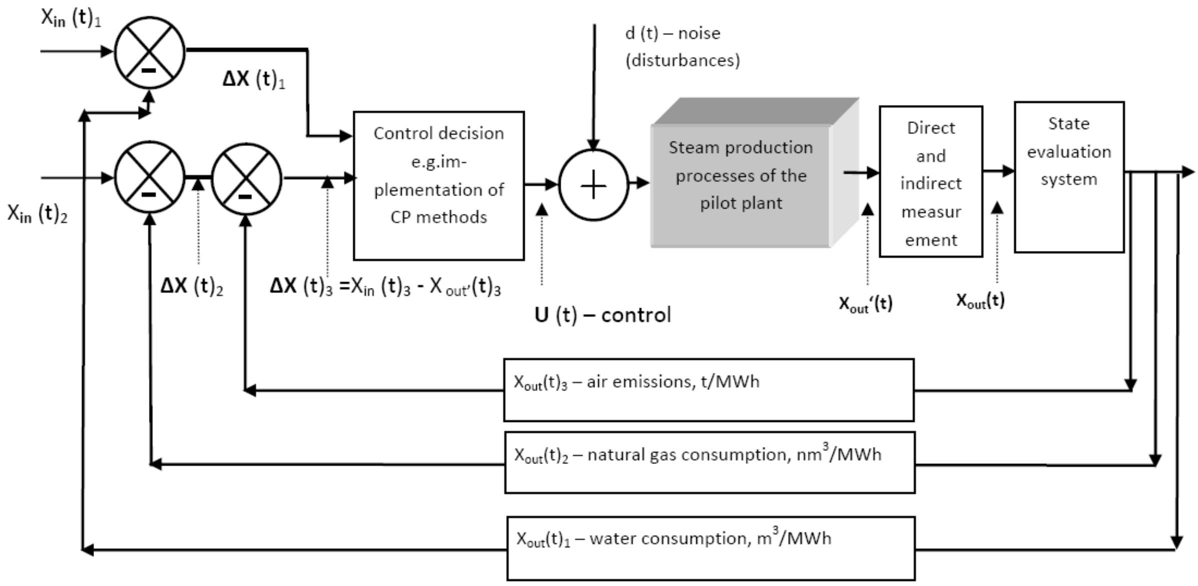

Fig. 5. *Control system of significant environmental aspects in the confectionary pilot plant*

5.2. Results of the feasibility analysis of implementing the automatic control system of air excess coefficient

The burning regime in a boiler has to be maintained within the optimal range of air excess coefficient (λ). In case the coefficient increases, NO_x emissions to the air also increase. In case the coefficient decreases lower than possible, CO air emissions increase, thus the fuel is ineffectively burning. Therefore, to produce the same volume of heat energy, it is necessary to burn the larger volume of fuel (Staniškis, Kliopova, et al. 2010). If the air excess coefficient decreases by only 0.1, the boiler house can save about 0.6-0.8% of fuel (Buineavičius, Pyragas 2009).

The experiment in the pilot plant has determined the value of the air excess coefficient: λ = 1.2-1.5. The exact control of the natural gas burning process, inc. the control of O_2/CO concentrations, allows keeping the air excess coefficient at the optimal value (λ = 1.03), which was evaluated by measuring and a control device for burning optimization. Thus, it has been evaluated that the plant can save up to 3% of natural gas (75.9 thousand nm^3/year) by decreasing λ to the optimal value. The emissions to the air will be decreased by 150 t/year (inc. CO_2).

Total investments to the control system are 22.6 thousand EUR.

5.3. Results of the feasibility analysis of condensate recycling to steam-boilers

Currently in the pilot plant up to 58 m^3 /day or 13.4 thousand m^3/year of condensate are discharged after technological processes into the sewerage system. The temperate of the condensate is 40-80^{0}C; therefore, before being discharged it is cooled. In order to save energy and soft water, the condensate is to be collected into the intermediate tank and then recycled in the steam production (Kliopova, Staniškis 2006). Thus, only 16 thousand m^3/year of soft water will be used for heat energy production.

Table 3. Results of environmental and economic evaluations of the alternatives of optimization of heat energy production process in the confectionary pilot plant

	Before CP		After CP		Savings / minimizing	
	units/year	EUR/year	units/year	EUR/year	units/year	EUR/year
Capacity of steam-boiler	6.54 MW		6.54 MW			
Natural gas consumption, thousand nm^3	2 434	639 092	2 051	538 750	383	10 0342
Heat energy production, MWh	19 655		17 000 *1 946		-	-
Total air emissions during natural gas burning, t inc. CO_2	4 667.22 4 638.69	1 443	3 932.9 3 908.87	1 216	734.31 729.82	227
Water consumption, m^3	33 650	34 035	15 670	15 849	17 980	18 186
Electricity consumption (in boiler – house and compressor), MWh	3 886	310 880	3 750	300 000	136	10 880
Total savings:						129 635

*Comment: *1 946 MWh/year of heat energy will be produced by condensing economizer*

Table 4. Results of evaluation of environmental performance after implementation of energy efficiency innovations in the confectionary pilot plant

	EI (before CP)	EI (after CP)	Achieved environmental performance
Energy intensity within the pilot plant	1.7 $MWh/t_{prod.*}$	1.4 $MWh/t_{prod.*}$	0.3 $MWh/t_{prod.}$
Heat energy intensity within the pilot plant	1.23 $MWh/t_{prod.*}$	1.18 $MWh/t_{prod.*}$	0.05 $MWh/t_{prod.*}$
Natural gas consumption	152 $nm^3/t_{prod.*}$	128 $nm^3/t_{prod.*}$	24 $nm^3/t_{prod.}$
	124 $nm^3/MWh_{h.e.**}$	108 $m^3/MWh_{h.e.***}$	16 nm^3/MWh
	1.4 $MWh/t_{prod.*}$	1.2 $MWh/t_{prod.*}$	0.2 $MWh/t_{prod.}$
Electricity consumption in boiler-house (and compressor)	0.24 $MWh/t_{prod.}$*	0.23 $MWh/t_{prod.*}$	0.01 $MWh/t_{prod.}$
Energy consumption for heat energy production	1.4 $MWh/MWh_{h.e**}$	1.2 $MWh/MWh_{h.e.***}$	0.2 MWh/MWh
Water consumption in boiler-house	2.1 $m^3/t_{prod.*}$	1.0 $m^3/t_{prod.*}$	1.1 $m^3/t_{prod.}$
Emissions into the air during heat energy production, t	0.3 $t/t_{prod.*}$	0.2 t/ $t_{prod.*}$	0.1 $t/t_{prod.}$
Heat energy cost for manufacturing of 1 t of production unit, Lt	62.5 $EUR/t_{prod.*}$	54.3 EUR/ $t_{prod.*}$	8.2 EUR $t_{prod.}$
Direct cost of heat energy production, Lt	51 $EUR/MWh_{h.e.**}$	46 $EUR/MWh_{h.e.***}$	5 EUR/MWh

Comment: EI –environmental indicators; $t_{prod.*}$ - production volume - 1600 t/year; $MWh_{h.e.**}$ - volume of produced heat energy before CP innovations – 19655 MWh/year, $MWh_{h.e.***}$ - volume of produced heat energy after CP innovations 18946 MWh/m.

In the pilot plant soft water for steam production is primarily heated from 10-15^{0}C to 100^{0}C; and then it steams. The average condensate temperature is 60^{0}C. For heating of 1 m^3 of water from 15 to 60^{0}C, 0.189 GJ of heat energy is used. In case the condensate is recycled, 709 MWh/year of heat energy will be saved; accordingly, about 84 thousand nm^3/year of natural gas will not be burnt.

To cool 1 m^3 of water from 80^{0}C to 45^{0}C (permissible temperature for waste water), 0.147 GJ of cooling energy is used. About 0.3 kWh of electricity is used in the pilot plant to produce 1 kWh of cooling energy. Therefore, to cool the condensate 165 MWh/year of electricity is consumed.

Electricity consumption will be only slightly increased due to installation of recycling pump (about 23.3 MWh/year).

The implementation of the condensate recycling project will allow saving about 14 thousand m^3/year of soft water, 140 MWh/year of electricity, and 700 MWh/year of heat energy or 84 thousand nm^3/year of natural gas.

The investments to the condensate recycling system are 42.7 thousand EUR.

5.4. Total environmental and economic effects

The results of the environmental and economic evaluations of all three CP innovations are presented in Table 3. The implementation of these innovations will allow minimizing natural gas consumption by 383 thousand m^3/year, emissions into the air by approx. 734 t/year, inc. CO_2, water consumption by approx. 18 thousand nm^3/year; electricity consumption by 136 MWh/year. The results of the evaluation of environmental performance are presented in Table 4.

Total CP investment of all three CP innovations is 210 900 EUR. The pay-back period is 1.63 years.

6. Conclusions

The analysis of the tendency of final energy consumption in Lithuania has identified the energy saving potential for Lithuanian food industry: 358.9 thousand toe/year or 0.038 thousand toe/EUR.

The results of the analysis of the implemented environmental projects in Lithuanian food industry show a great potential for increasing energy efficiency and thus decreasing energy intensity in production processes by implementing various methods of industrial sustainable development (see Paragraph 3).

The algorithm of the feasibility analysis of possibilities to increase heat energy efficiency in industrial companies has been introduced (see Paragraph 4).

The possibilities to minimize heat energy intensity are analyzed in the confectionary pilot plant. It is evaluated that the current heat energy intensity within the plant is 1.23 MWh/t_{prod}., thus about 152.14 $nm^3/t_{prod.}$ of natural gas are burned and about 0.292 $t/t_{prod.}$ of gas is emitted from the pilot plant boiler-house (see Paragraph 5).

Heat energy demand (19.7 MWh/year) is evaluated by developing material and energy balances of all technological processes (see Paragraph 5).

The fuel and energy balance in the heat energy production process is drawn up and efficiency of the burning process is evaluated. It has been identified that heat energy losses during energy production amount to over 13% (see Paragraph 5).

Main environmental aspects are evaluated and their control system and objective function are suggested to the pilot plant (see Paragraph 5).

Eleven environmental alternatives have been proposed for optimization of the heat energy production processes and minimization of the plant heat energy intensity. Three innovations have been selected for the feasibility analysis:

- Use of waste energy from exhaust gases (implementation of condensing economizer);
- Implementation of the automatic control system of air excess coefficient (λ);
- Condensate recycling to steam-boilers.

In case of implementation of the analyzed CP innovations:

- efficiency of heat energy production will increase by 14.4%;
- energy intensity within the pilot plant will decrease by 17.6%;
- heat energy intensity within the pilot plant will decrease by 4.07%;
- more than 10% of heat energy will be produced using waste heat energy (from exhaust gas);
- natural gas consumption will decrease by 15.8% - 0.2 MWh for producing 1 t of products, or 16 nm^3 for produced 1 MWh of heat energy;
- emissions into the air will decrease by 15.7% - 734 t/year, or 29 kg/MWh;
- water consumption in the boiler-house will decrease by 53% - 17 980 m^3/year, or 0.88 m^3/MWh;
- total energy consumption for the produce 1 MWh of heat energy will decrease by 14.2% - 0.14 MWh/MWh;
- the cost-price of heat energy production in the steam boiler for pilot plant will decrease by 9.8% - 5 EUR/MWh;
- CP investments (210 900 EUR) will payback after 1.63 years;

The results of the feasibility analysis show that control targets of heat energy production (see Fig. 5) will be reached. After application of the control decisions (CP innovations), state variables of the system will be better than planned:

- $X_{in}(t)_1$ =1 m^3/MWh,
- $X_{in}(t)_2$ =108 nm^3/MWh,
- $X_{in}(t)_3$ = 0.2 t/MWh.

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Šiluminės energijos intensyvumo mažinimas maisto pramonės įmonėse, taikant darnios plėtros metodus

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Tarp Lietuvos apdirbamosios pramonės šakų maisto produktų, gėrimų ir tabako gaminių pramonė sukuria daugiausiai pridėtinės vertės (PV), kuri 2009 m. sudarė 3,2 mlrd. litų, arba 24,2 proc. visos apdirbamosios pramonės sukurtos PV. Deja, Lietuvos maisto produktų ir gėrimų gamybos sektorius pasižymi gana dideliu energijos intensyvumu, kuris net 29 proc. didesnis už ES šalių vidurkį. Pagrindinis tyrimo tikslas – įvertinti šiluminės energijos gamybos efektyvumo didinimo galimybes maisto produktų gamybos įmonėse taikant švaresnės gamybos (ŠG) ir kitus pramonės darnios plėtros metodus. Tikslui pasiekti buvo nustatyti tokie uždaviniai:

- išanalizuoti galutinės energijos intensyvumo tendencijas Lietuvoje ir Lietuvos maisto pramonės įmonėse ir nustatyti efektyvumo didinimo galimybės ir tikslus;
- išanalizuoti ŠG prevencinių metodų diegimo galimybes maisto pramonės įmonėse;
- pasiūlyti šiluminės energijos efektyvumo didinimo algoritmą ir pritaikyti jį eksperimentui pasirinktoje konditerijos gaminių gamybos įmonėje.

Atliekant galutinės energijos intensyvumo tendencijų Lietuvoje analizę, Lietuvos maisto pramonės įmonėms nustatytas efektyvumo didinimo potencialas – 358,9 tūkst. tne/m., arba 0,038 ktne/EUR.

Eksperimentui parinktoje Lietuvos konditerijos pramonės įmonėje buvo analizuojamos šiluminės energijos intensyvumo mažinimo priemonės. Naudojant tyrimo metu pasiūlytą šiluminės energijos didinimo galimybių įvertinimo algoritmą, nustatyta, kad įmonėje šiluminės energijos sąnaudos produkcijos vienetui sudaro net 1,23 MWh/t_{prod}, t. y. sudeginama iki 152,14 nm^3/t_{prod} gamtinių dujų. Dėl to į aplinkos orą patenka iki 0,292 t/t_{prod} išlakų. Sudarant įmonės medžiagų ir energijos balansą, nustatytas šiluminės energijos poreikis – 19,7 MWh/m.

Atliekant garo katilo kuro energijos balansą, nustatyta, kad reikšmingi aplinkosaugos aspektai susieti su garo katilo žemu naudingumo koeficientu. Darbe pasiūlyta reikšmingų aplinkosaugos aspektų valdymo sistema, nustatyta tikslo funkcija. ŠG įvykdomumo analizei atlikti parinktos trys šilumos energijos efektyvumo didinimo inovacijos: kondensacinio ekonomaizerio įdiegimas garo katilinėje, oro pertekliaus koeficiento (λ) automatinio valdymo sistemos įrengimas ir kondensato grąžinimas į garo katilinę.

Įdiegus minėtas inovacijas:

- šiluminės energijos gamybos efektyvumas padidėtų 14,4 proc.;
- gamtinių dujų sąnaudos sumažėtų 15,8 proc. – 383 tūkst. nm3/m., arba 16 nm3 vienai MWh pagaminti;
- apie 10 proc. šiluminės energijos būtų gaminama naudojant atliekamą šiluminę energiją;
- degimo produktų išlakos į aplinkos orą sumažėtų 15,7 proc. – 734 t/m., arba 29 kg vienai MWh pagaminti;
- vandens sąnaudos šilumos energijos gamyboje sumažėtų 53 proc. – 17 980 m3/m., arba 0,88 m3/MWh;
- bendros energijos sąnaudos 1 MWh šiluminės energijos pagaminti sumažėtų 14,2 proc. (0,14 MWh/MWh);
- šiluminės energijos 1 MWh pagaminti savikaina, vertinant tiesioginius kaštus, sumažėtų 5 EUR/MWh (9,9 proc.).

ŠG inovacijų įdiegimas leistų sumažinti šiluminės energijos intensyvumą 4 proc. nuo 1,23 $MWh/\ t_{prod}$ iki 1,18 $MWh/\ t_{prod}$.

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