

IMPROVEMENT OF ENVIRONMENTAL PROTECTION THROUGH OPTIMIZATION OF THE PRODUCTION PROCESS - A CASE STUDY

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SUMMARY

Within the project Cleaner production, implemented by Cleaner Production Centre of the Faculty of Technology and Metallurgy, University of Belgrade, in cooperation with the Serbian Ministry of Environmental Protection and Spatial Planning, financed by the city of Pančevo and under the auspices of the United Nations Industrial Development Organization, undertaking of systematic actions and creation of policies has been planned in a company HIP Petrohemija with the aim of enabling realization of activities related to improvement of environmental protection by implementing technological changes in the production process and through better control of waste streams. The aim of the project is to improve raw material and energy efficiency, to minimalise the negative impact of the production cycles on the environment and to make real financial savings at the same time through corporate responsibility.

The overall results of the project show that the invested funds have a payback period of 3 years on average, made savings (primarily a decrease in gas consumption of 15,095,000 m³/y) reduce CO₂ emission for 36,230 t/y, while the energy consumption is reduced for 7 percent with the projected production volume increase of 20 percent while the project is ongoing.

By using HIP Petrohemija as an example, which is a company belonging to a group of bigger consumers of energy and electricity, it will be shown that there is a number of options of cleaner production especially when it comes to raw material and energy efficiency as it is an area where substantial saving can be made. The effects of implementation of different options of cleaner production are best seen through reduction of energents, water and electricity consumption and reduction of the negative effect on the environmental quality.

Key words: cleaner production, energy efficiency, waste streams control, environmental protection.

INTRODUCTION

United Nation Environment Program (UNEP) presented the concept of cleaner production in 1989 which defined cleaner production as “the continuous application of an integrated environmental strategy to processes, products and services to increase efficiency and reduce risks to humans and the environment” [1]. United Nations Industrial Development Organization (UNIDO), as one of the international organization which direct the development of cleaner production in the world, is recognized as a specialized provider of key services in achieving mutually combined challenges of reducing poverty through production, integration of different countries into global market through trade capacity building, encouraging environmental sustainability in industry and improving approaches to cleaner energy.

Developing countries have, with the help of UNEP and UNIDO, established national centers for cleaner production (over 50 centers all across the world). In the countries in South Eastern Europe, such as Croatia, Slovakia, Moldova, Hungary, Czech Republic, Bulgaria, Montenegro and FYROM, a number of cleaner production centers has been established, majority of which has a national character [2].

Removal or minimization of effects of processes and products on the environment represents the essence of cleaner production and its preventive strategy. Glavič and Lucman [3] define cleaner production as a systematically organized approach to production activities, which has a positive effect on environment and which encompasses resource use minimization, improved eco-efficiency and source reduction, in order to improve environmental protection and reduce risks to living organisms. According to Kjaerheim [4], cleaner production has proven itself to be an efficient way of reducing waste materials, energy consumption and emission levels, while at the same time it encourages positive preventive activities and it promotes holistic approach to resources, production, economy and environment. Basu and Van Zyl [5] claim that cleaner production describes processes with the emphasis on reduction of impact of the operational systems on the environment based on the implementation of improved management, methods and instruments strategies.

MATERIALS AND METHODS

The project Cleaner Production has been implemented with the help of the expert team of the Cleaner Production Centre of The Faculty of Technology and Metallurgy, University of Belgrade (an active member of UNIDO) in chemical industry Pančevo *Petrohemija jsc* under the auspices of the governments of Austria and Slovenia and Serbian Ministry of Environmental Protection and Spatial Planning.

HIP Petrohemija, which has been in business for more than 30 years, is one of the leading producers of petrochemical products in South Easter Europe. HIP Petrohemija was founded in 1972 as the third phase of chemical industry development in Pančevo. After selecting the most modern technology available at the time, originating mostly from the USA, 6 production plants were built: PENG (Low Density Polyethylene plant - LDPE), PEVG (High Density Polyethylene plant - HDPE), VCM, PVC, Etilen i Elektroliza (Ethylene plant), which are connected to each other through a ethylene and chlorine line, and the complex was completed with Utility Plant and Waste Water Treatment Plant, as well as numerous specialized centers, working units and services. By 1979, in all production plants of HIP Petrohemija, production was designed with the objective to produce more than one million ton of various petrochemical products per year.

The range of products of HIP Petrohemija consists of polymers: high density polyethylene, low density polyethylene, styrene-butadiene rubber as well as basic products – ethylene, propylene, C4 fraction, pyrolytic oil, pyrolytic gasoline, methyl-tertiary butyl ether and 1.3 butadiene. Other products include high density polyethylene compound (black and colored pellets), polyethylene pipes for water and natural gas and telecommunication pipes for protection of electroconductors.

The company implements integrated model of environment quality and protection management system and occupational health and safety management system, according to standards ISO 9001:2000 and ISO 14001:2004 and OHSAS 18001:2007.

Project aims and objectives

The aim of the project is to improve raw material and energetic efficiency, to minimalise the negative impact of the production cycles on the environment and to make real financial savings, by optimizing the processes and by using principle of prevention and reduction of waste streams, at the same time through corporate responsibility. Energetics has the greatest potential for improving and reducing consumption, which has a positive effect on the environment in the form of emission reduction. Improvement of environmental protection will be conducted through better control of waste streams too.

The Cleaner Production project included the Ethylene Plant, the LDPE and HDPE Plants, the Utility Plant and the Waste Water Treatment Plant.

The Ethylene Plant consists of the plant for thermal decomposition of virgin naphtha and the plant for pyrolytic gasoline hydrogenation and the projected annual capacity is 200,000 t of ethylene.

The Low Density Polyethylene Plant performs ethylene polymerization in a pressurized tank, under high pressures of up to 2,000 bar. Continuous production on one line, with the maximum

annual capacities of 57,000 t up to now, delivers pelleted products. The process technology allows for obtaining various products bearing different characteristics, with broad spectrum of applications (extrusion of films, foils and plates, blow-molded and injection-molded products).

In the *High Density Polyethylene Plant*, the ethylene polymerization process is performed on two identical production lines in the loop type reactors under medium pressures, which ensures high operation flexibility, with an aim to produce a large number of HDPE grades in the form of pellets and powder. Maximum achieved capacity on the two production lines is 76,000 t per year. High density polyethylene is processed with the use of various techniques: blow molding, injection molding, extrusion and pressing, whereby most diversified products are obtained – from household objects and technical parts, up to the gas and water distribution pipes.

The Energy Fluid Production and Distribution Plant – Utility Plant supplies all the plants of HIP Petrohemija with the required energy fluids and utilities. The continuous work of this plant, as well as the quality and the quantity of fluids produced, are the conditions for smooth, efficient operation of other production plants within the company.

The Waste Water Treatment Plant – WWT represents one of the most important links in the environment protection chain within HIP Petrohemija. A modern method for treatment of waste waters consists of an entire petrochemical complex closed sewage system, of a pre-treatment in the production plants, of a special treatment of caustic water flow from the Ethylene plant and of a central waste waters treatment plant. Primary treatment (equalization, neutralization, flocculation and flotation) and secondary treatment (two-stage biological treatment-through a bio-filter and active charcoal) are separately performed in the Waste Water Treatment Plant, as well as dehydration and stabilization of the extracted sludge.

Methodology

Project Cleaner production has been conducted through trainings and visits to the HIP Petrohemija, by organizing workshops for consultants and company representatives, through assessment and by suggesting possible solutions. In the period between March and October 2010 six workshops were held in order to master the theory and to realize practical activities in the companies, with the emphasis on mastering the methodology needed for rational consumption of resources and on defining working policies which would tend to minimalise the possibility of pollution occurring in the production process and to reduce the occurrence of negative effects. The lecturers were the experts from the Cleaner Production Center, which were joined by the international experts from Austria and Slovenia during the project.

Those who attended the workshops were trained in specific areas such as technology assessment from the point of view of cleaner production, energy efficiency, cleaner production policies, data management, multilateral environmental agreements (Kyoto protocol etc), occupational safety, introduction of environmental management system (ISO 14001) and others. The training also included raising awareness of the need for introduction of cleaner production. As a part of field training, HIP Petrohemija was visited by domestic and international expert and this is when the data were collected with the aim of reducing costs and negative effects on the environment.

Company's management supported the realization of the activities leading to the reduction of the negative influences on the environment and improvement of company's operations by actively participating in the activities.

RESULTS AND DISCUSSION

Petrochemical complex HIP Petrohemija belongs to a group of large consumers of heat and electric energy so attention was especially paid to Energetics, as an area with great potential for savings, which could be achieved by changing existing technological processes and improving other phases of the production cycle. Out of all of these suggested options for cleaner production, 75 percent of them are related to energy savings, most of which were realized during the project.

Cleaner Production Program

Table 1 Overview of options of cleaner production

CP Option	Investment €	Savings €/year	Payback period	Impact on the environment
OPTION 1 <i>Ethylene Plant</i> Partial replacement of raw materials	20,000 to 30,000	500,000	immediately	- Around 150 t of pyrolytic oil less (light distillation oil) and around 400 t of pyrolytic gasoline less at an annual level. - Reduction of CO ₂ emission from 1,700 t/y.
OPTION 2 <i>Ethylene Plant</i> Modification of Tk- 1101B tank roof	800,000	/	/	Reduction of total CO ₂ emission from 12 t/y.

OPTION 3 <i>Ethylene Plant</i> Pipeline installation with the objective to secure burning of regeneration effluent in pyrolysis furnaces	50,000	/	/	Elimination of unpleasant odours
OPTION 4 <i>Ethylene Plant</i> Overheating of water steam in the convection zone of furnaces and boilers	15,000,000 to 20,000,000	4,000,000 to 5,000,000	3-4 years	- Reduction of gas consumption of 15,000,000 m ³ /y. - Reduction of CO ₂ emission of 32,100 t/y.
OPTION 5 <i>Ethylene Plant</i> Change of the type of steam used for regeneration in pyrolysis furnaces	1,000	120,000	immediately	Reduction of feeding boiler water consumption of around 30,000 t/y, as well as substantial reduction of chemical consumption of around 20-30 t/y.
OPTION 6 <i>LDPE Plant</i> Change of 4.5 bar steam for 3.5 bar steam	No investment	15,000	immediately	- Reduction of steam consumption used for processes in the plant. - Reduction of crude oil consumption by 50 t/y. - Reduction of CO ₂ emission by 160 t/y.
OPTION 7 <i>LDPE Plant</i> Introduction of remaining condensate into the closed system	No investment	9,000	/	- Crude oil savings up to 30t/y. - Reduction of CO ₂ emission by 96 t/y.
OPTION 8 <i>LDPE Plant</i> Use of more concentrated initiator solvents	No investment	60,000	immediately	Savings in the amount of solvent

OPTION 9 <i>HDPE Plant</i> Reconstruction of complete OF Polymerization Section	1,960,000 (to install previously purchased equipment)	230,000	/	- Elimination of carbon hydrate emission into the air, and return to the polymerization sector. - Reduction of iso-butane consumption by 100 t/y.
OPTION 10 <i>HDPE Plant</i> Reconstruction in the activation section, installation of internal filter into the V-201 activator	40,000 (to install previously purchased equipment)	97,000	4-6 months	- Reduction of waste catalyst of 1,500 kg. - Reduction of furnace activation gas of around 30%.
OPTION 11 <i>Waste Water Treatment Plant</i> Covering the equalization and flotation pool	2,300,000	/	/	Elimination of unpleasant odours
OPTION 12 <i>Waste Water Treatment Plant</i> Installation of analyzer device for continuous monitoring of waste water quality on the Oil Refinery Pančevo line	250,000	/	/	Prevention of increased emissions and unpleasant odors in the working space air.
OPTION 13 <i>Utility Plant</i> Insulation of 50 noninsulated items (pipelines, valves, flanges, etc.)	15,000	43,750	4 months	- Energy savings. - Reduced CO ₂ emission by 288 t.

<p>OPTION 14 <i>Utility Plant</i> Repair and replacement of non-operative condensate separators in the Utility Plant and MPC</p>	5,000	84,000	Less than a month	<ul style="list-style-type: none"> - Energy savings. - Reduced CO₂ emission by 552 t/y.
<p>OPTION 15 <i>Utility Plant</i> Return of the return condensate from the heat exchanger from the administrative building and the laboratory</p>	15,000	17,280	10 months	<ul style="list-style-type: none"> - Energy savings. - Reduced CO₂ emission by 215 t/y.
<p>OPTION 16 <i>Utility Plant</i> Replacement of the driving device on the P-1201 B pump</p>	15,800	58,311	45 days in summer period	<ul style="list-style-type: none"> - Reduction of SM steam consumption – 1,857 t. - Reduced CO₂ emission by 213 t.
<p>OPTION 17 <i>Utility Plant</i> Replacement of the driving device on the P-1405 E pump or F (condensation turbines)</p>	1,000,000	1,870,000	1 year (due to the work in the summer period)	Avoidance of condensate production
<p>OPTION 18 <i>Utility Plant</i> Reconstruction and modernization of the system for management, leading, control and distribution of energy fluids</p>	1,000,000	500,000	2 years	By improving technological processes and procedures a reduction of energy consumption is achieved.

OPTION 19 <i>Utility Plant</i> The Utility Plant condensate system on inter-plant distributor	67,300	156,000	5 months	- Savings in condensate – 77,964 m ³ or savings in crude oil consumption 608 t/y. - Reduced CO ₂ emission by 1,950 t/y.
OPTION 20 Repair of 1mm diameter leaking places at 100 locations	11,000	35,000	4 months	- Reduction of steam production of 1,000 t/y, gas consumption of 80,000 Nm ³ or savings in crude oil consumption 72 t/y. - Reduced CO ₂ emission by 230 t/y.
TOTAL:	25,055,000	8,296,000	3 years	Total reduction of CO₂ emission is 36,230 tons per year

Source: Cleaner Production Centre, Serbia [6].

Description and effects of the suggested options of cleaner production

Partial replacement of raw materials - Ethylene Plant (Option 1)

By implementing partial replacement of raw materials within the production process, it has been made possible to gain more ethylene/propylene for the same price per ton of raw materials (2,5 percent compared to the total production of Petrohemija, up to 10 percent with major modifications) and to get less pyrolytic gasoline and pyrolytic oil, which contributes to the reduction of CO₂ emission from pyrolytic gasoline. At annual level, it means around 150 t of pyrolytic oil less (light distillation oil) and around 400 t of pyrolytic gasoline less. The overall effects of the replacement of raw materials amount up to 500,000 Euros at an annual level.

Modification of tank roof Tk-1101B - Ethylene Plant (Option 2)

This cleaner production option has primarily effect on the environment if we take into consideration that with better tank sealing, the emission of pollutants into the air is reduced that is evaporation of aromatics from pyrolytic gasoline, especially during tank filling and pumping is reduced. Furthermore, this leads to the reduction of total CO₂ emission from 12 t/y.

Pipeline installation with the objective to secure burning of regeneration effluent in pyrolysis furnaces - Ethylene Plant (Option 3)

Similarly to the previously discussed option, this option also has an effect on the environment as after the installation of the pipeline with the aim of securing burning of regeneration effluent in

pyrolysis furnaces, there was an increase in gas consumption during regeneration, but the environmental issue of unpleasant odors was resolved, which justifies the investment into this adjustment. Adverse environmental effect was eliminated in this way and in this way the company adhered to the measures issued by the Republic Inspection for Environmental Protection.

Overheating of water steam in the convection zone of furnaces and boilers - Ethilen Plant (Option 4)

Suggested option of cleaner production involves largest investments (15-20 million €) with the projected payback period of 3 to 4 years, and on the other hand these investments have provided greatest benefits to the environment. Namely, better use of smoke gas energy from furnaces and boilers leads to switching off of both steam overheaters, which again leads to reduction of gas consumption of 15,000,000 m³/y, and also to reduction of CO₂ emission of 32,100 t/y.

Change of the type of steam used for regeneration in pyrolysis furnaces - Ethylene Plant (Option 5)

With a minimal investment of 1,000 €, reduction of consumption of feeding boiler water of around 30,000 t/y, as well as substantial reduction of chemical consumption of around 20-30 t/y was made possible. This option leads to the savings of 120,000 € per year.

Change of 4.5 bar steam for 3.5 bar steam - LDPE Plant (Option 6)

The suggested option of cleaner production does not entail any investments, but it enables projected savings of around 15,000 Euros at an annual level. Namely, energy savings are made as the steam from the Utility Plant is reduced from 21 or 14.5 bar to 4.5 bar, and the current steam consumption is 9,600 t/y. LDPE Plant itself produces 3.5 bar steam (average consumption 150 t/month in the winter period) so is possible to use this steam in the process, instead of the 4.5 bar steam. This suggested option leads to the reduction of crude oil consumption by 50 t/y and it also leads to reduction of CO₂ emission by 160 t/y. This leads to the reduction of the amount of fines to be paid to the Environmental Protection Fund for emission of sulphure dioxide, nitrogen dioxide and other pollutants.

Introduction of remaining condensate into the closed system - LDPE Plant (Option 7)

With this option, that is by introduction of remaining condensate into the closed system amounting up to 0.5 m³/h of condensate released from a larger number of drainage points in the system, a direct positive impact is made on the environment and also crude oil savings up to 30 t/y and reduction of CO₂ emission by 96 t/y are achieved. This leads to the reduction of the amount of fines

to be paid to the Environmental Protection Fund for emission of sulphure dioxide, sodium dioxide and other pollutants. This solution can lead to savings of 9,000 Euros per year.

Use of more concentrated initiator solvents - LEPD Plant (Option 8)

With no investment, this option which is in laboratory testing phase, can result in savings in the amount of solvent needed which leads to savings of 60,000 Euros per year.

Reconstruction of complete OF Polymerization Section - HDPE Plant (Option 9)

Expansion of production capacity of polymer powder to 90,000 t/y involved elimination of all bottlenecks, polymer obturation, and also elimination of the S-205 A/B cyclone from the production process which led to the elimination of CO₂ emission into the air (the vent gases iso-butane and nitrate were directed into atmosphere through cyclone, which was used to separate polymer powder from gases), and their return to the polymerization sector. By the installation of the new isobutene nitrogen regeneration unit, regeneration of carbon hydrate from compound with nitrogen is performed, and it is then returned into process which leads to the reduction of losses of isobutene and nitrogen from the process and it also reduces the amount of dangerous gases released into atmosphere. Taking into consideration that High Density Polyethanyl Plant has two production lines and two vents, and their emission is 80 kg/h per line (total of 160 kg/h) which caused the reduction of iso-butane consumption by 100 t/y. By installing the previously procured equipment with the value of 1,960,000 Euros, the estimated savings amount up to around 230,000 Euros per year.

Reconstruction in the activation section, installation of internal filter into the V-201 activator - HDPE Plant (Option 10)

Reconstructing and installing the internal filter into activator allows for the reduction of waste catalyst generation in the amount of 1,500 kg which allows for financial savings based on the savings in investments in waste treatment and savings in utility raw materials/chemicals. Furthermore, in this way reduction of furnace activation gas of around 30% is achieved which resulted in savings of natural resources. Projected savings on an annual basis are estimated around 97,000 € per year.

Covering the equalization and flotation pool - Waste Water Treatment Plant (Option 11)

Implementation of this option makes an environmental impact which is reflected in reduction of potential emissions and unpleasant odors of waste substances (air ventilation above the pool, and referral to the burning unit or to some other form of treatment). Investment is 2,300,000 €.

Installation of analyzer device for continuous monitoring of waste water quality on the Oil Refinery Pančevo line- Waste Water Treatment Plant (Option 12)

The installation of analyzer device for continuous monitoring of waste water quality enables better monitoring of parameters of waste water coming from the Oil Refinery of Pančevo (a factory complex adjacent to Petrohemija) and it enables quicker reaction, in line with the joint instructions in case of deviation in monitored parameters' value. This also leads to savings in chemicals and quicker reaction time in order to avoid increased emissions and unpleasant odors in the working space air.

Insulation of 50 noninsulated items (pipelines, valves, flanges, etc.) - Utility plant (Option 13)

By insulating noninsulated items on pipelines, valves, flanges etc in the Utility Plant, savings of energy is made possible in the following ways: savings in steam production of 1,250 t, savings in gas consumption of 100,000 Nm³ and savings in consumption of electricity of 952 MWh (equivalent to 90 tons of crude oil). In addition, this leads to reduced CO₂ emission by 288 t/y and it reduces annual expenses for fines to be paid to the Environmental Protection Fund for emission of sulphure dioxide nitrogen dioxide and other pollutants. Total savings made with this option are projected at 43,750 Euros per year.

Repair and replacement of non-operative condensate separators in the Utility Plant and MPC - Utility Plant (Option 14)

By investing 5,000 Euros into repair and replacement of non-operative condensate separators savings of energy are made: savings in steam production of 2,400 t, savings in gas consumption of 192,000 Nm³ and savings in consumption of electricity of 1,829 MWh (equivalent to 172.3 tons of crude oil). CO₂ emission is reduced by 552 t and also annual expenses for fines to be paid to the Environmental Protection Fund for emission of sulphure dioxide nitrogen dioxide and other pollutants are reduced. Total savings made with this option are projected at 84,000 Euros per year.

Return of the return condensate from the heat exchanger from the administrative building and the laboratory - Utility Plant (Option 15)

By enabling return of the return condensate from the heat exchanger from the administrative building and the laboratory in the Utility Plant, savings of energy are made that is savings in condensate of 8,640 m³ and savings in electricity consumption of 605 MWh (equivalent to 67.3 tons of crude oil). This results in reduced CO₂ emission by 215 t/y and in reduced annual expenses for fines to be paid to the Environment Protection Fund for emission of sulphure dioxide nitrogen dioxide and other pollutants. Estimated savings go around 17,280 Euros per year.

Replacement of the driving device on the P-1201 B pump - Utility Plant (Option 16)

Activities regarding replacement of the driving device on the P-1201B pump are performed for the purpose of efficient steam balancing in the summer period (180 days a year), in order to avoid unnecessary production of 3.5 bar SL steam that ends up as excess on the condensator. This results in reduction of SM steam consumption of 1,857 t, and savings in gas consumption of 148,500 Nm³ (equivalent to crude oil consumption of 134 t). CO₂ emission is reduced by 213 t and so are annual expenses for fines to be paid to the Environmental Protection Fund for emission of sulphure dioxide nitrogen dioxide and other pollutants. Estimated savings with this option are 58,311 Euros per year.

Replacement of the driving device on the P-1405 E pump or F (condensation turbines) - Utility Plant (Option 17)

Replacement of the driving device on the P-1405 E pump or F is done in order to efficiently balance steam in the summer period and in order to avoid unnecessary condensate production. By installing an electrical motor instead of the turbines on the P-1405 E pump or F, it is possible to enter the zone of safety risk if a short or longer power cuts occur. An investment of 1,000,000 Euros enables savings of 1,870,000 Euros per year.

Reconstruction and modernization of the system for management, leading, control and distribution of energy fluids - Utility Plant (Option 18)

Reconstruction and modernization of the system for management, leading, control and distribution of energy fluids enables full automatization of production, consumption and use of energy fluids. This brings the share of energy in product price at the optimal level. The first phase involves reconstruction and modernization of the instrumentation for the key equipment in the Utility Plant (steam production, air production, cooling water), for control of production and distribution of energy fluids, whereas the second stage would involve reconstruction and modernization of the entire system of management, guidance, control and distribution of energy fluids. The payback period of the investment of 1,000,000 Euros is estimated at 2 years.

The Utility Plant condensate system on inter-plant distributor - Utility Plant (Option 19)

In the existing system, drainage from the condensate separator on the inter-plant distributor is released into the atmosphere, and by realizing the suggested option, it will be referred to the closed condensate system. This leads to energy savings: savings in condensate of 77,964 m³ and savings in electricity consumption of 5,457 MWh (equivalent to crude oil consumption of 608 t). CO₂ emission is reduced by 1,950 t and so are the annual expenses for fines to be paid to the

Environmental Protection Fund for emission of sulphure dioxide nitrogen dioxide and other pollutants. Estimated savings go around 156,000 Euros per year

Repair of 1mm diameter leaking places at 100 locations (Option 20)

By conducting repair of leaking places at more than 100 locations, energy savings are made: savings in steam production of 1,000 t, savings in gas consumption of 80,000 Nm³ and savings in electricity consumption of 762 MWh (equivalent to crude oil consumption of 72 t). CO₂ emission is reduced by 230 t/y and so are the annual expenses for fines to be paid to the Environmental Protection Fund for emission of sulphure dioxide, nitrogen dioxide and other pollutants. Estimated savings with this option is 35,000 Euros per year.

Cleaner Production Project Results

Table 2 Realization of suggested options

CP Option	Date	Realization	CP category	Feasibility
OPTION 1	May 2012	90%	S - Substitution of raw materials	1 - immediately feasible
OPTION 2	May-Oct 2013	90%	T - technological changes	1 - immediately feasible
OPTION 3	March 2011	100%	T - technological changes	1 - immediately feasible
OPTION 4	September 2013	100%	T - technological changes	1 - immediately feasible
OPTION 5	May 2011	100%	T - technological changes	1 - immediately feasible
OPTION 6	May 2011	100%	T - technological changes	1 - immediately feasible
OPTION 7	May-June 2011	100%	T - technological changes	1 - immediately feasible
OPTION 8	September 2011	100%	T - technological changes	1 - immediately feasible
OPTION 9	March 2011	100%	T - technological changes	1 - immediately feasible

OPTION 10	April 2012	100%	T - technological changes	1 - immediately feasible
OPTION 11	June 2013	50%	T - technological changes	1 - immediately feasible
OPTION 12	October 2013	60%	T - technological changes	1 - immediately feasible
OPTION 13	May 2012	80%	G - Good housekeeping	1 - immediately feasible
OPTION 14	May 2012	75%	G - Good hosting	1 - immediately feasible
OPTION 15	November 2011	60%	T - technological changes G - Good housekeeping	1 - immediately feasible
OPTION 16	November 2011	100%	T - technological changes G- Good housekeeping	1 - immediately feasible
OPTION 17	April 2012	-	T - technological changes	2 - feasible after some time
OPTION 18	February 2013	-	T - technological changes	2 - feasible after some time
OPTION 19	March 2012	90%	T - technological changes G - Good housekeeping	1 - immediately feasible
OPTION 20	May-July 2011	100%	G - Good housekeeping	1 - immediately feasible
Average realization:		79.75%		

Source: HIP Petrohemija [7]

Indicators of the Cleaner Production Project

The project Cleaner Production contributed to the rationalization of usage and reduction in consumption of raw materials and energy sources. Indicators which demonstrate the most significant results achieved in the period between 2010 and 2013 are shown in the following table.

Table 3 Indicators of the most significant achieved results

Indicators	Consumption					Specific consumption* (normative)			Difference 2010/2013	
	Unit	2010	2011	2012	2013	unit	2010	2013	Norma- tive	%
Electricity	kWh	203,567,063	195,635,283	98,076,258	193,759,565	kWh/t	387.2	303	84.2	21.74
Fuel (oil fuel)	T	5,317	7,486	14,375	0.00	kg/t	10.12	0	10.12	100
Raw Water	m ³	3,069,973	3,761,447	1,537,500	1,504,447	m ³ /t	5.84	2.35	3.49	59.76
Natural Gas	N/m ³	105,461,052	100,121,061	52,521,439	75,644,350	m ³ /t	200.57	143.86	56.71	28.27
Total energy	MJ/t	8,473	8,045.5	11,459	7,885.3	MJ/t	8,473	7,885.3	587.7	6.93

*Specific consumption is calculated on the basis of total production: 2010 - 525,795 t; 2013 - 639,338 t.

Source: HIP Petrohemija [7, 8, 9, 10]

Financial year 2012 was characterized with two long breaks in production. The first break was caused by the need to reduce the amount of consumed electricity with the aim of protecting the energy system of the Republic of Serbia and it was used for reconstruction of the plant. The second, longer, break was provoked by the shortage of raw gasoline in July, and in August a decision was brought on the realization of the investment project “The reconstruction of PF section of HDPE plant up to 90,000 t of powder per year“ which had an effect on the production plan which was realized with only 34 percent. Financial year 2013 passed without any standstills in production.

By analyzing options of cleaner production and based on the comparison of results of reduction in the specific consumption (normative) in the period between 2010 and 2013, and taking into consideration the increase in the production of 21.6 percent in 2013 compared to 2010, together with improvement of economic efficiency and substantial financial savings, a significant reduction in the adverse effects to the environment and generated pollution has been noted due to the reduction in the consumption of oil fuel, water and natural gas. The results of the analysis undoubtedly confirm the reduction in the consumption of the total energy per ton of products of 6.93 percent with the increase of the production volume of 113,543 tons of products.

By increasing the energy efficiency and occupational safety with advanced automated processes, an enhancement of ecological performances was achieved and this is reflected in the complete regeneration of isobutene and nitrogen, removal of emission of fine powder into

atmosphere and water and elimination of emission of solid waste catalysators into atmosphere, which led to a decrease of production costs and maintenance costs, and at the same time a number of breaks in production was decreased and easier removal of bottlenecks was enabled.

Substantial savings of 4,140,000 € were made in the period between 2010 and 2013 due to the reduction in the specific consumption (normative).

Improvement of control of the waste streams

Systematic waste management in HIP Petrohemija provides control over further treatment and disposal of all kinds of waste, which is generated in the course of business. An important part of this system is making and conducting a waste management plan that defines measures which are to be followed during collecting, classification, storage and regular waste disposal. Records of the produced, storage or transported waste are kept in the organizational units and collectively in Environment protection service.

Taking into consideration that waste management is the implementation of the prescribed measures of waste management in the collection, transport, re-utilization and waste disposal, including supervising of these activities and care on disposals after closure, waste management in HIP-Petrohemija jsc is performed in the way which ensures the least risk to harm health and life of people and the environment by exercising control and adhering to reduction measures: water, air and ground pollution; danger for plant and animal life; danger of the accidents, fire and explosions; negative impact on the area and natural resources of the special value and the level of noise and unpleasant odors.

Waste management in HIP Petrohemija is performed in accordance with the Waste Management Plan. The plan identifies all wastes (types, composition and quantities), methods and ways of different waste types separation, and defines waste flows, ways of its storage, treatment and disposal, by applying the wastes hierarchy management principles, defines measures to be undertaken in order to decrease waste production, protective measures against fire and explosion, and measures for protection of environment and people health.

Produced waste is handed over to the authorized operators who have licenses issued by competent bodies for waste management, for their further disposal (storage, treatment, export).

In the following table, an overview of types and amounts of waste for the period between 2010 and 2013 is given.

Table 4 Types and amounts of waste for the period 2010 - 2013

Year	2010		2011		2012		2013	
Waste Type	Produced (t)	Disposed (t)	Produced (t)	Disposed (t)	Produced (t)	Disposed (t)	Produced (t)	Disposed (t)
Non-hazardous	3,168.5	78.4	3,544.2	103.3	1,801.6	125	3,260.2	302.1
Hazardous	89.4	11.8	449.9	61.6	588	24.3	403.4	1,577.6

Source: HIP Petrohemija [7, 8, 9, 10]

Through analysis of the types and amounts of waste in the aforementioned period, by modernizing equipment and plants as well as by introducing new technologies and by applying appropriate technological processes which allow for more advance control of waste streams, an important datum arises and that is the amount of disposed hazardous industrial waste that is all types of hazardous materials and by-products which are created during certain technological process and which are according to their characteristics (flammability, explosiveness, toxicity, irritability, infectiousness etc) dangerous for people and environment. This points out the readiness and decisiveness of the company's management to be more responsible and decisive when it comes to the disposal of hazardous waste and to take this problem, as one the most important ones when it comes to the environment, a step further.

CONCLUSION

HIP Petrohemija has chosen to contribute to the strategy of efficient management through systematic environmental protection management. Company's management thinks about the consequences of the pollution in the long run, it plans solutions and it reacts to the occurrences of pollution by applying the most modern technology in accordance with the international standards as well as by working incessantly on improving results of different process which are involved in the protection of the environment and work surroundings by using energy optimally, reducing emission into air, water and land and by reducing and disposing of produced waste.

HIP Petrohemija invested around 17,350,000 € into this project which resulted in a high degree of realization of suggested options that is approximately 80 percent. The effects of the realization of the options of cleaner production are especially noticeable when you take into consideration the reduction in specific consumption of energy sources and water which resulted in the total savings of more than 4,140,000 €.

In addition to the aforementioned options, a number of other activities, unrelated to the project, which will be strategically important for energy efficiency and environmental protection:

reconstruction of the furnaces for naphtha pyrolysis, reconstruction of preheaters and boilers, installation of pretreatment of oily wastewater, installation of a new storage tank for propylene, realization of the project for plant for odor control and treatment of industrial waste water, sanation of stabilized sludge landfill, reinstrumentation of sections for polymerization and finalization etc.

Company's dedication to reducing the impact of the company on the environment is incessant. By combining our experts' knowledge and the best available techniques, strictly adhering to all requirements prescribed by law, HIP Petrohemija successfully controls its influence on the working and living environment. HIP Petrohemija monitors and analyses the impact of pollutants coming from its plants on the air. The quantity of pollutants in the air is objectively and timely reported to the competent authorities, local government and all other stakeholders. Air emission of dangerous substances usually originates from the combustion plant, and to a lesser extent from terminals and from a waste water treatment system and this emission is below the emission limit values prescribed by the law.

HIP Petrohemija continues with the well established trend of improving waste management systems, by investing into temporary waste and secondary material storage facilities, by equipping containers for separate waste collection, as well as by educating the employees. Waste management is performed in such a manner so as to avoid the slightest risk of causing harm to the health and lives of people, or to the environment by exercising control and by implementing measures of reduction of water, air, and land contamination.

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