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CLEANER AND ENERGY EFFICIENT PRODUCTION: A CASE STUDY

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Abstract

A project called 'Cleaner Production' is conducted in the organization of the Cleaner Production Centre of Serbia at the Faculty of Technology and Metallurgy, University of Belgrade and the United Nations Industrial Development Organization (UNIDO). The goal of the project is to perceive critical places in a company and define measures which would achieve significant financial savings and, at the same time, protect and improve the condition of the environment with minimal investment, by saving resources and energy. Complete results of the project demonstrate that the means invested are, on average, returned within a year, whereas savings achieved reduce the emission of CO_2 by the total of 4,000 t/year, the amount of solid waste by 1,000 t/year and the amount of energy and water consumption in some companies will be reduced by as much as 10%. On the example of the 'Hipol' AD company, it will be demonstrated that there is a large number of cleaner production options precisely in the energy efficiency section and that very significant savings were achieved there. The plant is one of major consumers of heat and electric energy and the team paid most attention precisely to energetics, as the area with the highest saving potential. The present state is mostly affected by the inability to transfer from a liquid fossil fuel (fuel oil) to a gas fuel, considering that there is no natural gas distribution nearby. Out of suggested options, more than 60% refer to energy savings most of which were realized during the project. Effects of cleaner production options realization are especially visible through the reduction of specific consumption of energy sources and water – since 2008 savings have accumulated to over € 120,000.

Keywords: chemical industry, cleaner production system, energy savings, environment, financial saving

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1. Introduction

The important role of technology in reducing environmental impacts of industrial activities is also emphasized on the international level, for instance, through the United Nations Environmental Programme (UNEP), which brought in the concept of Cleaner Production (Radonjič and Tominc, 2007). During the last two years of this program, several international and national organizations or agencies, such as the *United* Nations Industrial Development Organization (UNIDO), have directed the development of cleaner production in the world. The experience regarding the application of the cleaner production program in the world has shown that a large number of countries have achieved progress by applying an appropriate system of measures and actions for cleaner production promotion and development. Developing countries have created special programs aimed at raising awareness regarding cleaner production and encouraging its implementation, whereas developed countries have been more concentrated on the development and application of new regulations. In UN member countries, cleaner production has been seen as the first step towards acquiring an integrated license and fulfilling conditions prescribed by the Integrated Pollution Prevention and Control Directive (IPPC

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Directive). With the help of UNEP and UNIDO, developing countries have established national centers for cleaner production (over 50 centers in South America, Asia, Africa and Europe). In countries of the south-east Europe region, in Croatia, Slovakia, Moldova, Hungary, Czech Republic, Bulgaria, Montenegro and Macedonia, a lot of cleaner production centers have been formed, most of which have national character.

Cleaner production in the world today is globally recognized as a proven strategy for increasing the efficiency of natural resource management and waste minimization (UNEP, 2001). The term Cleaner Production was defined by UNEP in 1990 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" (UNEP, 1990). Cleaner Production is at the transitional stage between pollution prevention and sustainable development. It goes beyond pollution prevention by explicitly incorporating conservation of materials, energy and other natural resources, and by strengthening the value-adding aspect of processes. It is however not a sustainable development concept, since it is not explicitly aimed at the integration of social equity objectives (van Berkel, 2000).

Cleaner production (CP) methodology is a preventive strategy directed at elimination or minimization of the impacts of production processes and products on the environment (Taylor, 2006). The application of CP methodology leads to economically and environmentally efficient products through sustainable use of energy, raw materials, chemicals and water in the production processes via process modification, input material substitution and on-site reuse/recovery (Daylana et al., 2013). The main task of the CP implementation within a company is decreasing the environmental impact of the company's activities by implementing CP options which give not only environmental benefits (Xie et al., 2013), but also an economical effect (Kliopova and Staniskis, 2004; Tosovic et al., 2016). CP methods have significant financial and economic advantages as well as environmental benefits at the local and global level (Ozbay and Demirer, 2007). Five basic techniques of CP implementation are: good management, process optimization, raw material change, new technology and new product development.

1.1. The strategy of cleaner production implementation in the Republic of Serbia

Joining and entering the European Union represents a strategic choice of the Republic of Serbia towards a modern society with developed economy, where requests made by the EU are the means and not the goal of the development of the Republic of Serbia. Joining the EU implies making postulations regarding one's own development and stability. The goal of activity in the environment area is creating conditions for adjusting the structure and dynamics of economic and other efforts, i.e. processes in the environment, in order that satisfying the needs of present generations does not endanger the right of future generations to a healthy environment, at the same or a higher level.

Serbia's national strategy for entering the European Union regarding the environment area defines a very large number of activities whose function is conformity with the EU's requests, which can all be included in the instruments the function of which is protection of the environment (regulations, development and expansion of inspection, issuing permits and consent, monitoring, border control etc.). In the area of incentive elements, the strategy anticipates the use of the environment management system (EMS) in accordance with SRPS ISO 14001:2005 and the EU's environment management and check system (*Eco Management and Audit Scheme* - EMAS), ecological marking and good laboratory practice, and indicates the existence of funds for financing investments in the environment sector, especially in the area of solving the problem of hazardous waste, waste water issues and the reduction of pollution from thermal, mining and metallurgical plants. On the one hand, the strategy of cleaner production implementation in the Republic of Serbia is based on all adopted relevant strategies as well as on publicly available drafts of strategic documents, and on the other it is in accordance with the appropriate legislation. It represents direct concretization and elaboration of the National Sustainable Development Strategy (the Government of the Republic of Serbia, 2008). The strategy's objective is to operationalize and concretize activities related to the implementation and promotion of cleaner production methods and actions, and to create institutional conditions for their application and realization. The Strategy is thus manifested as an instrument of the policy of accomplishing sustainable development in all economic sectors and activities (Fig. 1). The role of cleaner production is to proactively create conditions in which results where everyone gains – both the social environment and the company are expected. The Strategy is necessary for the integrated and synchronized acceptance of cleaner production in all industry sectors.

Through its activities, Strategy realization will provide incentives to companies to apply the cleaner production approach. Cleaner production also engages in technical and technological production aspects, approaching the environment protection problems in all areas and at all levels. In a company's operations, the environment protection management is approached in a manner that makes it a permanent element of the sustainability of its development. In the observed example of 'Hipol' AD, cleaner production refers to one of its activity areas, i.e. to energy efficient production where cleaner production requires the highest possible level of energy efficiency and preservation of energy resources.

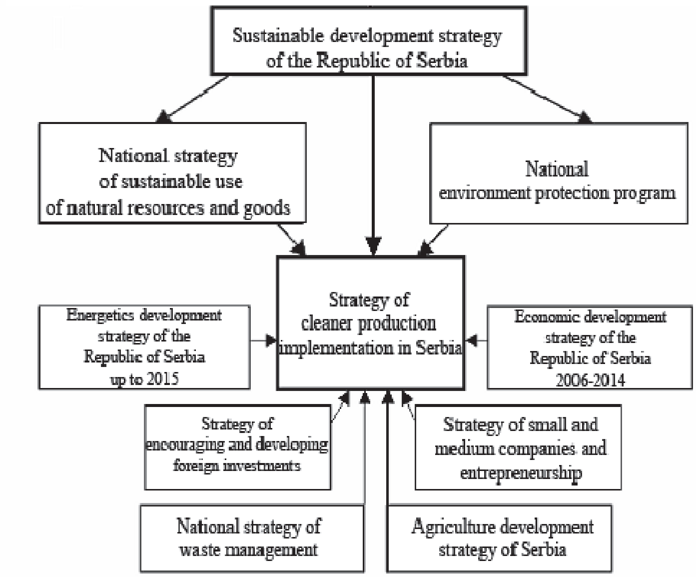


Fig. 1. The relation between the Cleaner Production Strategy implementation and other strategies (the Government of the Republic of Serbia, 2009)

The primary principles the Strategy is based on, besides the principles established in the National Sustainable Development Strategy, are the integration principle, prevention and precaution principle, economy principle and energy efficiency and waste minimization principle. The energy efficiency principle requires rational use of energy, i.e. elimination or minimization of energy losses both in the consumption sector and the energy production sector. Increase in energy efficiency significantly influences business improvement, i.e. increased competitiveness of business entities on domestic as well as global market of goods and services. In addition to the economic benefit, increase in energy efficiency significantly contributes to the environment protection through the reduction of greenhouse gas emissions.

1.2. Energetics development strategy of the Republic of Serbia up to 2015

Key elements of Serbia's new energy policy are: Basic objectives, Priority programs chosen from the objectives accomplishment aspect and appropriate social-state Measures and Instruments enabling the realization of chosen Priorities.

Instruments for accomplishing objectives/realizing Priorities are 'embodied' in the new legislative and institutional framework for work and business of energy subjects and in reorganizing the structure of the existing power companies and their work and business, primarily in market-regulated conditions and then on the liberalized and competition-free energy market. As logistic support to these instruments, specific programs are to be provided, such as Programs regarding Energy efficiency, New renewable energy sources, Environment protection, Scientific research and technology development, Vocational education and staff training for existing and completely new activities in energy industry, including the introduction of a modern Energy statistics system and issuing of an additional-specifically energetic regulation for performing energy activities in new conditions, in the country as well as the environment. Programs mentioned represent basic premises for realizing the objectives of Serbian energy development Policy/Strategy, as well as for creating the surroundings for achieving sustainable socio-economic development of the country. The mentioned expectation stems from the realization that only the trained-for-market entities of the energy production systems and the increase in the economic effectiveness and energy efficiency of energy utilization, with an acceptable level of endangering the environment, can enable the mentioned development of Serbia in the following period (Government of the Republic of Serbia, 2004).

1.3. Present situation in Serbian companies

Establishing the energy management system is more than necessary for organizations in Serbia. The reason is that Serbia is one of the countries with the worst results regarding energy efficiency and that such treatment of energy is directly reflected in the cost of domestic products and reduction of competitiveness of Serbian companies on the world market. Likewise, the significance in relation to accompanying effects on the environment should not be neglected. All of this places energy efficiency and better energy management in Serbia in the spotlight. The reasons lie in considerable potential that exists in relation to energy savings, reduction of accompanying costs as well as in the reduction of greenhouse gas emissions.

In Serbia, it is essential for organizations to realize that the potential savings can achieve better energy management, thereby achieving significant cost savings and better financial performance in terms of environmental protection, and with that an improved competitiveness in the market. In doing so, it should be borne in mind that much of the savings can be achieved with relatively modest financial investment: through the host business, better planning and organization, as well as activities that include routine maintenance of equipment.

New standards for energy management systems EN 16001:2009 and ISO 50001 have the overall goal to help organizations establish the systems and processes necessary to improve energy efficiency. Both of these standards largely follow the structure of ISO 14001:2004 (International Organization for Standardization, 2004), thereby facilitating their integration, although they can be applied independently. Regarding ISO 14001 standard, the benefits that the company may derive from introducing the environmental management system ISO 14001:2004, among other things include: decrease of expenses, a more rational usage of energy-generating products, reduction of negative impacts on the environment, ecological accidents risk reduction and so on (Živković et al., 2013).

Briefly, the establishment of the organization's energy management requires the following:

– To establish a national energy policy;
– To identify which activities in the organization are accompanied by the highest energy consumption;
– To identify the applicable legal requirements and other requirements to which it agrees, and which concern the energy;
– To identify priorities and set appropriate general and specific goals and specific action plans;
– To establish an appropriate structure and programs for the implementation of policies and achievement of goals;
– To facilitate planning, control, monitoring, implementation of preventive and corrective measures, verification and review of activities to ensure that the policy will be reconciled and that the energy management system will remain appropriate (British Standards Institution, 2009).

Within the system of environmental management, the issue of energy consumption could be included as one of the environmental aspects. One of the reasons for the implementation is that in practice organizations are often not fully aware of the whole structure of their energy consumption, because they do not have adequate measurement established or they do not deal with the analysis of energy consumption in a systematic way. Thus it happens that organizations do not have information on the real energy consumption per individual energy consumers, production lines and the like, nor do they recognize the interdependence of energy consumption and activities performed within the organization. Even the information on the energy losses often remains hidden due to the out-dated or insufficiently well-maintained equipment, increased energy consumption due to oversized capacity etc.

The energy management system encourages an organization to approach energy use in a systematic way now, focusing on specific values, structure and distribution of energy, defining priorities accordingly, defining objectives, their implementation and especially the continuous persistence in these tasks, thus achieving constant improvements in the established system. What is also important is that the energy management system includes the generation of certain records. Among the most important is the record related to the monitoring of selected parameters of energy performance. Another one that is significant is related to comparing values from year to year in relation to the starting position within the organization itself, but also to external comparison by benchmarking with the best in the particular sector.

However, note the following: the implementation of the energy management system does not necessarily mean its certification. Neither does it necessarily imply high costs. On the contrary, the implementation of energy management can lead to significant savings, sometimes through a very modest investment. It should be noted that good results in the field of energy efficiency are achieved in organizations with established management systems (such as ISO 14001 and ISO 9001), but also in organizations without a formally established management system.

The Cleaner Production Center has been active since 2007 as part of the UNIDO project ‘Establishment and Operation of a National Cleaner Production Center in Serbia’ whose program’s objective is building a national capacity for the application of the cleaner production concept primarily through a dialogue between state organs and industry. Since 2007, more than 70 companies have introduced the concept of raw material efficiency and cleaner production and 60 national experts for cleaner production have been trained.

Based on the example of the ’Hipol’ AD Industry of polypropylene and plastic products, it will be shown that a large number of cleaner production options are precisely in the area of energy efficiency and that significant savings have been achieved there.

2. Case study

One of the companies participating in the “Cleaner Production” project, which is conducted in the organization of the *Cleaner Production* Centre of Serbia *at the Faculty of Technology and Metallurgy, University of Belgrade and* UNIDO, based in Vienna, is the ‘Hipol’ AD chemical industry whose primary activity is manufacturing polypropylene granulate out of liquid polypropylene (Fig. 2). The company ‘Hipol’ AD was founded in 1976, while the production started in 1983. The Plant was built based on the Mitsubishi Petrochemicals Company licence.

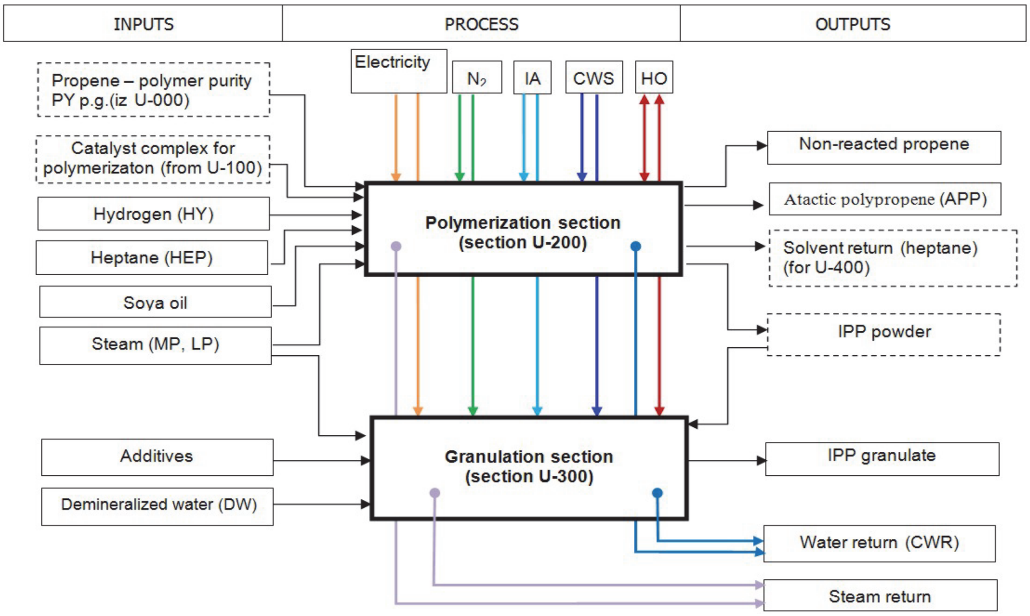


Fig. 2. Process diagram - polymerization and granulation sections ('Hipol' AD, 2008)

The company operates with a 100% of its production capacities, producing approximately 32,500 tonnes of isotactic polypropylene granulate.

Production of polypropylene granulate is carried out by the means of classic suspension polymerization in heptane, which is used as a solvent. The specified technology provides high product purity, which can be used even for the most delicate applications. Propene used as the main raw material i.e. monomer in the polymerization process is delivered to the Plant by rail from the company Petrohemija, Pancevo.

In spite of the fact that the company operates with a 100% production capacity, its production is still small compared to other European plants of the same type. The management of the 'Hipol' AD strongly encourages material and energy savings, measures aimed at taking care of the employees and the environment, i.e. the implementation of sustainable development principles as a main precondition for the company's long and continuous presence on the market. Environmental management system implemented in the company is such that all employees who are part of the decision making chain are involved in solving problems related to the issues important for environmental improvement.

2.1. The aim, subject and phases of the project

The aim of the project is to investigate critical positions in the company and to define the measures that will achieve significant financial savings while maintaining and improving the environment with minimal investment, saving resources and energy. In achieving this goal, formation of expert teams for finding solutions of material and energy efficiency which would lead to reduced environmental pollution is promoted, especially the creation of a team within a company in order to achieve continuity of work even after the project is finished.

UNIDO project of the Cleaner Production Centre of Serbia (CPCS) in the company 'Hipol' AD includes the plant for the production of polypropylene (PP) and other facilities of maintenance and energy - boiler room, compressor room, chemical water treatment (CWT) and Waste Water Treatment (WWT) ('Hipol' AD, 2008).

Phases of the project are:

– Phase I - Introduction of the project and the establishment of the Cleaner Production team;

– Phase II - Development of the technological process scheme;

– Phase III - Input of material and energy balances including waste in the worksheet with the cost accounting;

– Phase IV - Consideration of options regarding raw materials and energy savings as well as improvement of the environment;

– Phase V - CPD expert team report on the current state with identified deficiencies and suggestions for improvement and the implementation of measures for eliminating defects;

– Phase VI - Audit facilities and the preparation of reports.

2.2. Methodology

During the training, the CP Training Toolkit was used. Training included theoretical knowledge acquisition and practical activities realization in industrial companies. The cleaner production team consists of management, energetics, environment protection, production, maintenance, supply and legal service representatives, as well as experts appointed by the Cleaner Production Center. Team leaders are, at the same time, members of the Cleaner Production

Centre of Serbia workshop. The primary goal of forming a cleaner production team is better work coordination, higher quality of ideas and information exchange. The support of the 'Hipol' AD management to the Cleaner Production project is significant.

The given case study includes Serbian management system standards SRPS ISO 14001:2005 which have been conformed with the international standard for implementing the environment management system ISO 14001:2004.

3. Results and discussion

The plant is one of major consumers of heat and electric energy and the team paid most attention precisely to energetics, as the area with the highest saving potential. The present state is mostly affected by the inability to transfer from a liquid fossil fuel (fuel oil) to a gas fuel, considering that there is no natural gas distribution nearby. Out of suggested options (table 1), more than 60% refer to energy savings most of which were realized during the project.

3.1. Cleaner Production Program 2008

The influence on the environment defined by the Cleaner Production Program 2008 was determined using modern procedures and methods by the Cleaner Production Team of the 'Hipol' company, which consists of management, energetics, environment protection, production, maintenance, supply and legal service representatives, as well as experts – members of the Cleaner Production Center *at the Faculty of Technology and Metallurgy, University of Belgrade. When estimating the influence on the environment, the team's goal was to set optimal values of reducing the factory's harmful influence on the environment by taking into consideration real possibilities for the implementation of specific activities within the given option, their guidance being the procedure which is in accordance with the relevant EU Directive regarding the estimation of influence on the environment* 85/337/EC, established also by the Law on *the estimation of influence on the environment, and by adopting relevant rules.*

Table 1. Cleaner Production Programme options overview (Vukadinovic et al., 2009)

CP option	*Investments €*	*Saving €/year*	*Investment return*	*Impact on the environment*
OPTION 1 Reduction of water quantities: a) Raw water abstracted b) Discharged waste water	/	14,000	immediately	Decrease of consumption of chemicals for water treatment, reducing electricity spending and reducing amount of waste water
OPTION 2 Reduction of cooling tower energy consumption	/	31,000	immediately	Reducing electricity spending for 770 MWh/y, ie reduction of CO_2 emissions by 770 t/y
OPTION 3 Reduction of produced steam pressure from 12 bar to 6 bar	/	35,000	immediately	Reduced consumption of fuel oil for 87 t/y and reduce CO_2 emissions by 281 t/y
OPTION 4 Reversible osmosis plant for demineralised water production	24,500	40,000	7-8 months	Reduction of sludge removal and desalting of boilers, and with that energy losses. Reduced consumption of fuel oil up to 100 t/y, i.e. reduce CO_2 emissions by 323 t/y
OPTION 5 Reduction of steam quantities used for torch sustainment	15,000	67,000	3 months	Reduced consumption of fuel oil up to 168 t/y i.e. reduce CO_2 emissions by 543 t/y
OPTION 6 Condensate return from heating substation	3,000	9,000	4 months	Reduced consumption of fuel oil 21 t/d, i.e. CO_2 reduction for 68 t/y
OPTION 7 Reduced steam consumption in the boiler house	6,000	28,000	3 months	Reduced consumption of fuel oil 71.5 t/d, a reduction of CO_2 emissions by 230 t/y.
OPTION 8 Control of excess air in the process of heavy oil combustion (O_2 reduction from 6% to 2%)	50,000	50,000	1 year	Reduced consumption of fuel oil 125 t/d, a reduction in CO_2 emissions by 404 t/y
OPTION 9 'Hipol' AD technical water self supply	3,900	12,000	4 months	Reducing the amount of exhausted water from underground aquifers for 15,000 m^3/y
OPTION 10 Integration of waste water treatment and fresh water treatment plants into one process unit	20,000	25,000	10 months	Reduction of carbonate mud for min. 150 t/y. Reduction of chemical treatment to 50%.
OPTION 11 Other activities to improve waste and hazardous substance management	30,000	-	-	Prevent contamination of soil, water; better use of raw materials and a small amount of waste disposed in landfills
TOTAL:	**152,400**	**311,000**	**6 months**	Reduction of **CO_2 – 2,619 t/y**

3.2. Description and effects of the proposed Cleaner Productions options

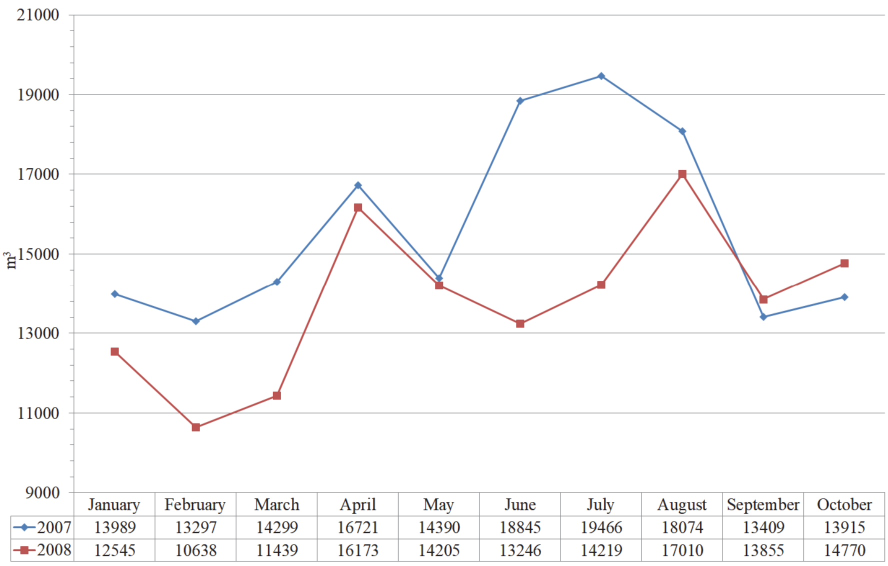
3.2.1. Reduction of water quantities (Option 1)

(1a) Reduction of water intake i.e. raw water consumption

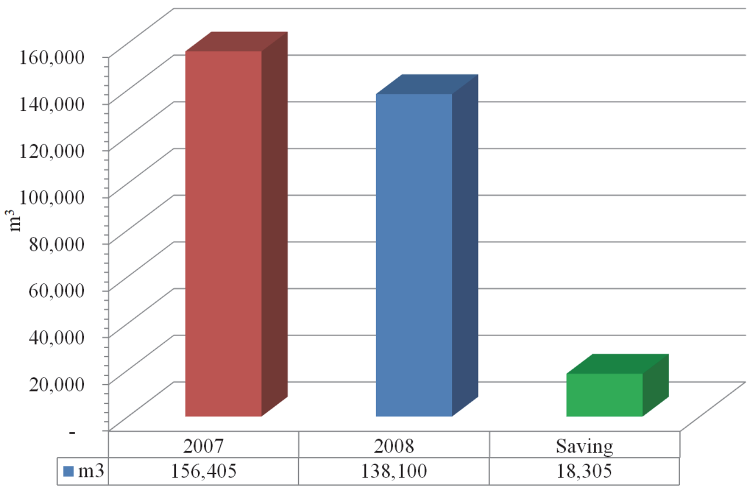
Water management measures carried out during 2008, involving measures aimed towards water loss reduction and water use rationalisation, resulted in reduced overall water consumption compared to the data from the year before. Smaller water quantities used in water treatment plant resulted in 10% lower consumption of chemicals used for water treatment, reduced power consumption for pumps and water transport (113,000 kWh) and reduced fees payable for water use from the Danube-Tisa-Danube channel. The overall savings resulting from reduced raw water consumption equal € 6,500. The total reduction of raw water is 18,305 m^3 (Fig. 3).

(1b) Reduction of discharged water i.e. treated waste water quantities

Rationalisation of raw water use, as well as the use of water produced in the water treatment plant, mostly contributed to the reduction of waste water quantities and consequently the reduction of water discharge from the waste water treatment plant. Data on the quantity of water discharged from the waste water treatment plant during the first 10 months of 2008 showed a reduction of 21% compared to the same period from the year before. The effects of reduced water discharge are as follows: 20% lower chemical consumption for water treatment, lower electricity consumption for waste water treatment plant operation and lower costs of waste water removal from the plant. The overall savings resulting from reduced treated waste water quantities equal € 7,500. The total reduction of discharged water is 23,584 m^3 (Fig. 4).

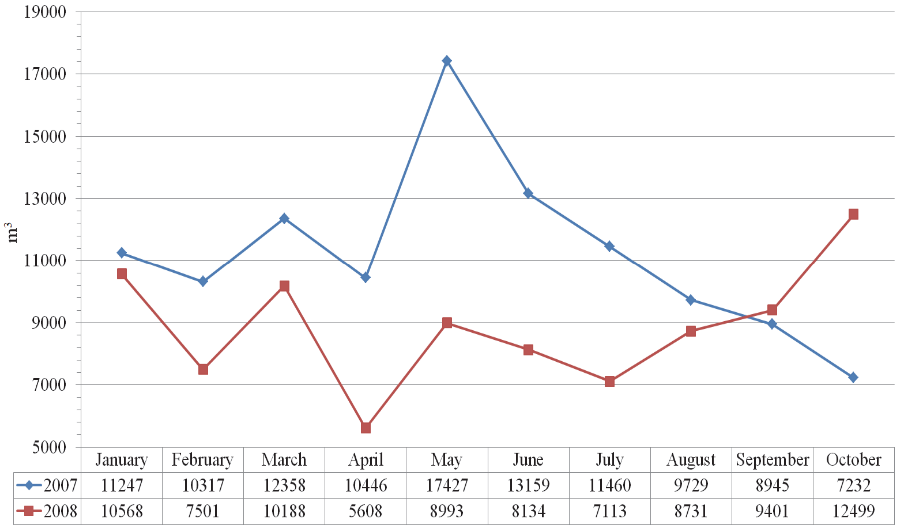


(a)



(b)

Fig. 3. Reduction of water intake – (a) raw water consumption by months and (b) total reduction of raw water consumption (own source)



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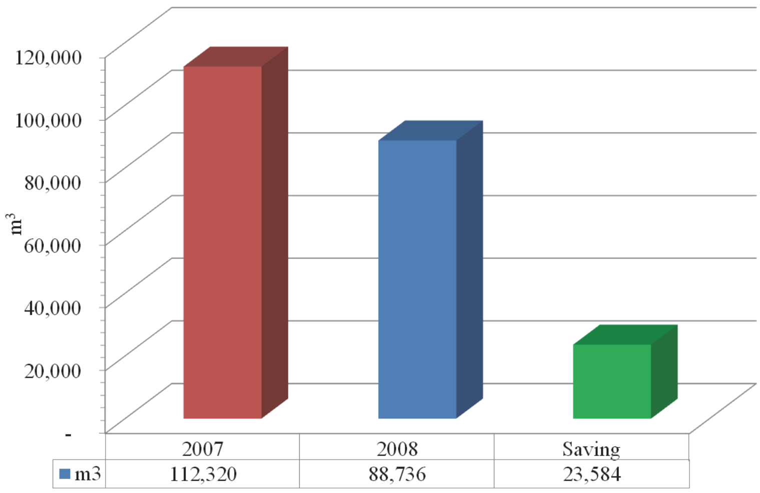

(b)

Fig. 4. Reduction of discharged water – (a) treated waste water quantities by months and (b) total reduction of treated waste water quantities (own source)

3.2.2. Reduction of cooling tower energy consumption (Option 2)

Cooling water required for the Polypropylene Production Plant's operation is supplied by means of a cooling tower. Cooling water is transported utilizing the cooling water pumps, providing the water circulation of 1,800 m^3/h. Up to this year, two cooling water pumps, 240 kW each, have been used to enable the cooling water transport. Cooling water transport by means of just one operating pump in the winter period (October-March) was carried out, imposing no effects on the cooling system's operation.

The effects of described one-pump operation in the period March-October 2008 were manifested through the reduction of consumed electricity in the amount of 736,630 kWh (Fig. 5). Reduced electricity consumption also produced important environmental benefits manifested through CO_2 emission reduction of 736 t (emission factor for Serbian national grid equals 1 t CO_2/MWh).

3.2.3. Reduction of produced steam pressure from 12 bar to 6 bar (Option 3)

Boilers in the boiler house of the Plant produce 12 bar saturated steam. The steam pressure is later reduced to 6 bar and 3 bar. Analysis of steam consumption led to the conclusion that consumption of medium pressure (MP) steam at 12 bar represents 4% of the total steam produced. Furthermore, a possibility for MP steam process consumers to use LP steam at 6 bar was also considered. Programme implementation started in August 2008, resulting in effects shown in Table 2. Reduced rate of heavy oil consumption per one tonne of steam produced is directly related to the reduction of steam production pressure. 0.7 kg lower heavy oil consumption per one tonne of steam produced was noted in August 2008, while the reduction in September 2008 equalled 1.7 kg. Based on the difference between the specified norm and the steam production, it is concluded that the consumption of heavy oil was lowered by 5.73 t in August and by 13.57 t in September.

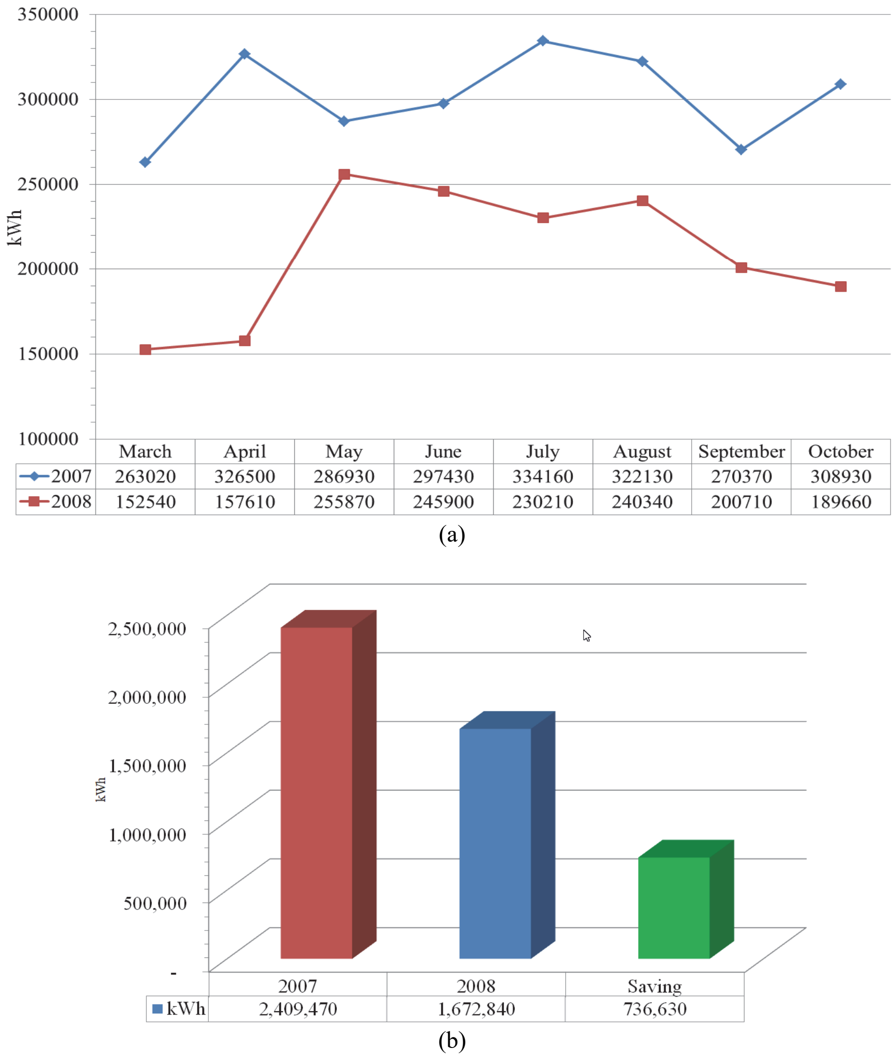

Fig. 5. (a) Reduction of cooling tower energy consumption by months and (b) total reduction of cooling tower energy consumption (own source)

Table 2. Effects of produced steam pressure reduction

Period→		April-July	August	September
Parameter↓	unit	p = 12 bar	p = 8 bar	p = 6,5 - 7 bar
Steam production	t	35,051	8,187	7,983
Heavy oil consumption	t	2,365	565.5	524.4
Rate: heavy oil /steam	kg/t	67.5	66.8	65.8

Source: 'Hipol' AD, 2008.

It is expected that 87 t reduction of annual heavy oil consumption can be accomplished. Reduced heavy oil consumption, besides the financial benefits, also results in environmental improvement, observed through a 281 t/a reduction of CO_2 emission. It should be noted that specified CO_2 emission reduction was calculated based on the heavy oil emission factor of 76.8 kg CO_2/GJ.

3.2.4. Reversible osmosis plant for demineralised water production (Option 4)

Water produced by neutral ionic exchange is used in the boiler house i.e. in the boilers. Inappropriate quality of such water is the main reason for frequent boiler desludging and desalting, resulting in considerable heat losses. Based on the quantities of hot water being disposed during the above mentioned process, it is calculated that annual heat loss, expressed in terms of fuel consumed, is equivalent to annual heavy oil consumption of 100 t. Procurement and installation of reversible osmosis plant, to be used for demineralised water production, would result in elimination of heat losses resulting from boiler desludging and desalting, primarily due to high quality of newly produced water.

Apart from the expected financial benefits resulting from reduced heavy oil consumption of 100 t/a, described measure would also lead to environmental improvements observed through annual reduction of CO_2 emission equal to 323 t.

3.2.5. Reduction of steam quantities used for torch sustainment (Option 5)

The main purpose of the steam used to sustain the torch is to provide cooling of the torch tip and its fume-free combustion. In 2007 steam consumption for the specified application equalled 12,567 t, which represented 11.7% of total steam produced. During the first 9 months of this year, torch related steam consumption was decreased by approximately 1.4 t/h. Due to the previously specified high share in the overall steam consumption, it was decided to set a goal of reaching a 20% reduction in torch related steam consumption. During the overhaul carried out in October, it was noted that steam control valve for the steam distribution to the torch was damaged and the appropriate repair actions were carried out (the new valve was ordered). Torch related steam consumption before and after the overhaul is shown in Table 3. During the first 10 days following the overhaul and control of the valve repair, the torch related steam consumption was reduced by 21.7% compared to the average steam consumption before the overhaul. Expected savings in the heavy oil consumption equal 168 t/a. Reduced heavy oil consumption shall contribute to CO_2 emission reduction of 543 t/a.

3.2.6. Condensate return from heating substation (Option 6)

Heating substations used for heating the premises in winter periods operate in a manner that enables a steam to water heat transfer by means of a heat exchanger. The pressure of the steam used in the substation equals 3 bar. Due to the previously absent condensate return, condensate from the two heating substations was discharged into the sewer system. Measurements of the discharged condensate quantities showed that the resulting heat loss, expressed in terms of fuel consumed, is equivalent to heavy oil consumption of 21 t over the heating period. A carried out reconstruction provided for a condensate, which had been discharged from the system for years, to be returned into the process (collector and a pump for condensate transport).

Apart from the expected financial benefits resulting from reduced heavy oil consumption of 21 t/a, described measure also contributed to environmental improvements observed through annual reduction of CO_2 emission equal to 68 t/a.

3.2.7. Reduced steam consumption in the boiler house (Option 7)

Boiler house uses 10% of its self-produced steam for its own needs. A 3 bar pressure steam is used for:

– Water heating in the condensate tank (return condensate and additional water from the water treatment plant);

– Boiler feed water degassing and heating;

– Heavy oil heating in the heavy oil heaters and tanks.

The most significant steam quantities of 10,675 t/a are used for water degassing and heating in the feed water and condensate tanks. Discontinuous fresh water supply to the condensate tank and discontinuous water transfer from the condensate tank to the feed water tank, passing through a degassing device, along with improper steam flow regulation for water heating in two previously specified tanks, contributes to significant steam losses. It is estimated that provision of continuous water feed and improvement of steam regulation would lower the boiler house steam consumption by 10-20%. Converted to heavy oil, the expected savings are 71.5 to 143 tons annually. Reduced heavy oil consumption would directly contribute to environmental improvements through reduced CO_2 emission.

3.2.8. Control of excess air in the process of heavy oil combustion (Option 8)

Principles of cost effective fuel combustion define a requirement for combustion process to be carried out in an environment with small quantities of excess air, which is especially important for heavy oil combustion. Data acquired from the combustion control system (flue gas analyzer), indicate that oxygen concentration varies between 4% and 7%, corresponding to an excess air coefficient of λ=1.3-1.6. Flue gas temperature varies between 210°C and 240°C, representing a considerable deviation from the design value of 180°C and in that manner resulting in an energy loss. High oxygen concentration in flue gases is a result of out-dated and non-flexible air intake regulation system of the boilers, especially important during boiler load variation. Replacing the current air regulation system with a modern system would result in fuel savings of 125 t/a. Reduced heavy oil consumption would in turn lead to reduced CO_2 emission of 404 t/a.

3.2.9. 'Hipol' AD technical water self supply (Option 9)

Since water treatment plant is able to produce several types of process water of different quality, it was decided that decarbonised filtered water should be used as technical water in 'Hipol' AD water supply system. 'Hipol' AD water supply system was connected to the equipment installed in the water treatment plant. In addition, pH regulation and water disinfection equipment was also installed.

Provision of technical water for sanitary use, washing and personal hygiene was carried out in June 2008. Appropriate analysis of technical water indicated that water quality is in accordance with the Rulebook on Hygienic Quality of Potable Water and that it can be used for intended purposes. Due to the low quality of water supplied by the town's water supply system, employees were provided with drinking water from the water balloons at the water pouring stations. The effects of the program are shown in Table 4.

Table 3. Torch related steam consumption before and after the overhaul

Steam consumption→		***Total consumption***	***Daily consumption***	***Hourly consumption***
Period ↓	***unit***			
01.01 - 30.09.2008	t	9,046.20	33.02	1.376
13.10 - 22.10.2008	t	259.8	25.98	1.082
Difference in consumption:	t		7.04	0.293

Source: 'Hipol' AD (2008)

Table 4. The effects of the technical water self supply program

Content	***unit***	***June***	***July***	***August***	***September***	***October***	***Total***
Technical water	m^3	593	1,438	793	1,887	1,010	**5,721**
Savings	€	533.7	1,294.2	713.7	1,698.3	909	**5,148.9**

**The price for the water from the town's water supply system for 'Hipol' AD is 0.9 €/m³; Source: 'Hipol' AD (2008)*

Apart from expected financial benefits, the program described has another dimension manifested through reduced exploitation of ground water aquifer that the town uses as its water source.

3.2.10. Integration of waste water treatment and fresh water treatment plants into one process unit (Option 10)

Efficiency of waste water treatment plant enables discharged water quality to be the same and in some parameters even better that the quality of fresh water taken from the Danube-Tisa-Danube channel and used in the water treatment plant (Fig. 6).

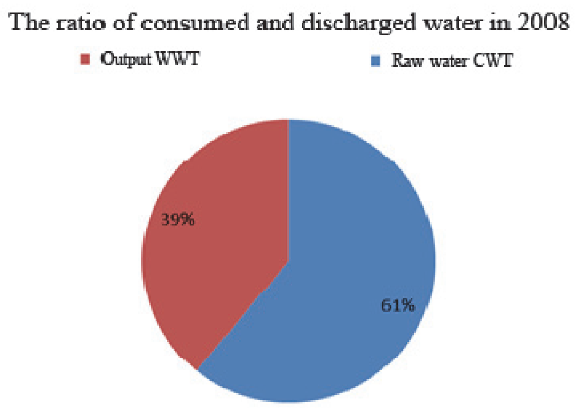

Fig. 6. The ratio of consumed and discharged water in 2008 (own source)

Having in mind the costs of fees that 'Hipol' AD is paying for water intake from the channel and the fees for water discharge into the same channel, there is a justified interest to enable the use of treated waste water that is being discharged as the fresh water consumed in the water treatment plant. Such use would enable integration of two specified plants into one process unit, providing water circulation in the system.

Apart from expected financial benefits manifested through significant reduction of fees payable for water intake and water discharge, the above measure would provide reduced consumption of chemicals used in fresh and waste water treatment plants. In addition, important environmental benefits would result from additional protection of water resources and reduced carbonate sludge deposition of 150 t/a.

3.2.11. Other activities to improve waste and hazardous substance management (Option 11)

(11-a) Waste and hazardous substance management

In order to establish integral and optimal waste management, certain activities are conducted starting from its creation, through its collection, transport, storage, treatment, until its final disposal, with the purpose of creating preconditions for reducing risks regarding the environment and people's health to an acceptable level, as well as minimizing waste which directly affects the reduction of business costs by reducing the costs of waste disposal.

Waste generated in the Plant complex is mainly sold as a secondary raw material. Hazardous waste mainly contains used oils remaining after the equipment maintenance, during which the new oil is refilled instead of the old. Annual quantities of these oils are not uniform and vary from 0.5 to 0.2 t. Oil quantities remaining after the maintenance activities larger than the specified are very rare. Used oils are returned to the manufacturer or are sent to refineries for treatment. There is no reimbursement for used oil return.

During the Cleaner Production Project implementation, several actions were conducted in order to correct irregularities observed by the experts during the site visit:

– A special area was provided for barrels which were kept in the open;

– Concrete base was built and a plateau was installed in the heavy oil tanking station.

Investments associated with the above activities were minimal (about € 400), while the benefits were multiple – from soil and water pollution prevention to easier handling and recovery from possible future accident, while at the same time being in harmony with the regulatory provisions regulating the issue in question.

A separate area was provided for new oil storage, temporary storage of used oils, as well as an area for chemical storage. Each of those storage areas were equipped with sun protection and a ceramic tile base which was slightly concaved and connected to the oily water sewage system. Proper ventilation was provided in all storage areas. Closed containers were provided for paper, metal and plastic sorting, resulting in considerable improvement of secondary raw material management.

(11-b) Improving work conditions

The new management of 'Hipol' AD was committed to providing workers with adequate and decent work conditions. Thus, some activities otherwise due to be performed during 2008 were also desirable in relation to the Cleaner Production project. Those are primarily the following activities:

– Sanitary blocks were rearranged;

– Toilets were retiled, new showers were bought and other sanitary equipment was exchanged;

– Places for workers to get changed were rearranged; old wardrobes were replaced with new ones.

This was successively done throughout 'Hipol' AD in places the workers occupy. The total investment for this work was about € 20,000 and the value of the total investment for option 11 was € 30,000.

3.3. Cleaner Production project's results 2008. Indicators of Cleaner Production Project 2008

Application of Cleaner production program (table 5) contributed to the rationalization of use and reduction of raw materials and energy consumption. The indicators shown in the table 6 present the most important savings realized during the project.

Effects of the cleaner production option implementation are especially observed through the savings resulting from the reduced consumption of energy sources and water which have up to date accumulated to € 120,000. Similar results of other conducted studies that include analysis of cleaner production options also indicate significant savings.

For example, in a study of cleaner production options assessment in the Shouguang Alcohol Factory, China (fermenting with thick wort, reusing CO_2, reconstructing distillation system and producing organic fertilizer and methane with alcohol lees liquid) savings of 421,300 $ per year were achieved (Guo et al., 2006), in Dalian pharmaceutical plant, China (biochemical alterations to waste water treatment system, phosphorus removal equipment, ammonia concentration recycle and design of off-gas treatment system) brought the total savings of 5.46 mln $ during 2009 (Zhi-dong et al., 2011), while the economic implications of the process of using waste from the distiller to the total production of ammonia-soda of two Polish factories are such that the actual savings are about $ 2.2 mln $ per year (Kasikowski et al., 2004).

All studies mentioned, besides the improvement of economic efficiency and significant financial savings, confirm considerable reduction of harmful effects on the environment and pollution creation, i.e. they undoubtedly prove that investing in cleaner production has a long-term effect on the company's better economic results.

Table 5. Realization of proposed options

CP option	*Term*	*Realization*	*CP category*	*Feasibility*
OPTION 1	Jan-Oct 2008	100%	G – good management	1 – immediately feasible
OPTION 2	Mar-Oct2008	100%	T – technological change	1 – immediately feasible
OPTION 3	Aug-Oct 2008	100%	T – technological change	1 – immediately feasible
OPTION 4	Oct 2008	100%	T – technological change C – change of raw material	1 – immediately feasible
OPTION 5	Oct 2008	100%	G – good management T – technological change	1 – immediately feasible
OPTION 6	Sep 2008	100%	G – good management	1 – immediately feasible
OPTION 7	Nov 2008	80%	T – technological change G – good management	1 – immediately feasible
OPTION 8	Mar 2009	-	T – technological change	2 – feasible after some time
OPTION 9	June 2008	100%	C – change of raw material G – good management	1 – immediately feasible
OPTION 10	Apr2009	-	T – technological change	2 – feasible after some time
OPTION 11	June-Oct 2008	80%	G – good management O – organiz. change	1 – immediately feasible
Average realization:		**78%**		

Source: 'Hipol' AD (2008)

Table 6. Indicators of the most important savings realized during the project

Indicator	*Absolute consumption*			*Spec. consumption*			*Differences 2007/2008*	
	Unit	*2007*	*Jan-Oct 2008*	*Unit*	*2007*	*Jan-Oct 2008*	*Index*	*%*
Electricity	kWh	23,720,261	19,370,917	kWh/t	731.00	711.00	20.00	2.74
Heavy oil	t	7,212	5,840	kg/t	222.20	214.40	7.80	3.51
Raw water	m^3	181,139	138,100	m^3/t	5.60	5.10	0.50	8.93
Waste water	m^3	133,779	88,736	m^3/t	4.12	3.26	0.86	20.87

** Specific consumption is based on production IPP: 2007 - 32,455t; Jan-Oct 2008 - 27,245t. Source: 'Hipol' AD (2008).*

4. Conclusions

UNIDO Cleaner Production Project has played an important educational and motivational role in the improvement of resource management and environmental protection in the 'Hipol' AD complex. The essential managerial decision and strong project support have contributed to remarkable project results. During the project implementation, local and broader public have been informed in more detail about the project activities in the company, which has contributed to improved company's reputation, especially among the local population.

'Hipol' AD has up to date invested approximately € 80,000 in the project, which has resulted in more than 70% of proposed options being implemented. Effects of the cleaner production option implementation are especially observed through the savings resulting from reduced consumption of energy sources and water which have up to date accumulated to € 120,000.

Apart from the described options, a series of sub-project activities have been initiated during 2008 which shall be of strategic importance for the energy efficient and environmentally friendly operation of the Plant in the following years:

– Cogeneration implementation – a Study and a Basic Design has been developed for a 4 MW faculty;

– Transition from heavy oil to gas – magisterial gas pipeline extension to the area is a precondition;

– Use of 18,500 MWh/a waste heat from the polymerisation process;

– A 2 MW plant for biogas production by the means of anaerobic digestion of agricultural solid residues;

– ISO 14001:2005 certification.

Team work and work methodology employed during the Cleaner Production Project shall continue to be used in the future since they have proven to be very successful. Future steps shall be taken towards the integration of all aspects of business practice into a unique risk atlas, containing different risk aspects such are those associated with the environment, product quality, occupational health and safety, as well as financial aspects.

Such approach shall provide a comprehensive business management and enable the company to take timely actions towards overall improvements, creating conditions for successful development and a good relation with the surroundings. In comparison with other companies, the results mentioned anticipate that realizing cleaner production measures in practice will result in significant savings.

The implementation of cleaner production in the Republic of Serbia requires further strengthening of the legal framework related to the environment, i.e. its realization in practice especially through creating and issuing by-laws which refer to: environment quality standards and emission standards; EMS systems, ecological sign, import and export of substances which damage the ozone layer, import, export and transit of waste, hazardous substance management, monitoring and pollutants register development as well as introduction of economic instruments. In that sense, it is necessary to considerably simplify all procedures related to issuing licenses and authorizations for the introduction of eco products and cleaner production actions.

Furthermore, it is necessary to create conditions for the formation and successful action of the ESCO (Energy Service Company) and MISCO (Material Input Service Company) arrangement. They are affirmed types of business organization that have been proved efficient in developed countries and their goal is the increase in economy's energy and material efficiency.

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