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IMPLEMENTATION OF CLEAN TECHNOLOGIES IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

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Rezumat. *Articolul prezintă conceptul dezvoltării durabile şi evoluţia lui în timp. Autorii analizează posibilităţile de promovarea a tehnologiilor curate în contextual dezvoltării durabile. Sunt prezentate şi analizate avantajele dezvoltării durabile şi a folosirii tehnologiilor curate pentru atingerea obiectivelor legate de schimbările climatice. Autorii au prezentat şi analizat un studiu de caz referitor la folosirea unei tehnologii curate în industrie. Studiul de caz se referă la modificarea unui cuptor prin introducerea unui recuperator de căldură din gazele de ardere pentru preîncălzirea aerului de combustie. Rezultatele analizei energetice, economice şi de mediu indică că folosirea acestei soluţii conduce la economii de energie, economii financiare şi la diminuarea impactului asupra mediului. În concluzie se arată importanţa dezvoltării durabile şi implicaţiile tehnologiilor curate în sectorul energiei.*

Abstract. *The article presents the concept of sustainable development and its evolution over time. The authors analyse possibilities for promotion of clean technologies within the context of sustainable development. There are presented and analysed advantages of sustainable development and of utilisation of clean technologies for achieving the targets linked with climate changes. The authors have presented and analysed a case study regarding utilisation of a clean technology in an industrial sector. The case study is referring to modification of a furnace through introduction of a heat recovery unit from flue gasses for pre-heating of combustion air. The results of the complex energy, economic and environment analysis show that utilisation of this solution leads to energy and financial savings and to reduction of the environment impact. In conclusion there is shown the importance of the sustainable development and the implications of clean technologies in the energy sector.*

Keywords: Sustainable development, clean technology, environment pollution, energy efficiency

1. General aspects regarding the concept of sustainable development

During the entire human history the energy issue was, still is and will remain the main problem on which depends the future development. The major challenges of the XXI century is to ensure the access of each individual of the Planet Earth to the clean (non-polluting), sustainable and at reasonable cost energy. The words

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"sustainable", "sustainable development", "sustainable economy" are frequently used today, maybe too frequent, starting with Parliaments when adopting laws and strategies of development of different countries, Governments – in their programs, political parties in their election programs and local public authorities and companies, which should transpose into everyday life this concept of development.

The words **"sustainable"** and **"sustainable development"** are relatively new, and have been launched in use by the UN Brundtland Commission (at that time Gro Varlem Brundtland was the Prime-Minister of Norway and at the same time the President of UN Commission) in the report "Our common future" in 1987. The commission has defined the concept of sustainable development as ***"a development that satisfies the needs of the present without compromising the capacities of future generations to satisfy their own needs***´(UN Organisation, 1987) [1]. Taking into consideration that energy production (conversion) from fossil fuels leads to environmental pollution, increased danger for human health, climate changes, etc., the concept of sustainable development has been accepted first of all within the context of development of energy sector. Thus, at the UN Conference regarding Climate Change, which took place in 1992 in Rio de Janeiro, has been formulated a more complex definition of the sustainable development concept. The sustainable development means a process of economic development that will have as a result the increasing level of life without destroing the eco-system of our Planet [2-3].

This means a well-ordered use of natural resources in such a way that every human on the Planet should have its own part of clean environment, as well as the obligation to try to improve it in order to ensure for its children a better chance.

During the millennia the humanity has used only renewable energy sources for satisfying its needs – solar radiation, woods, wind and flowing water, the last ones being derived from solar energy.

Starting with XIX century there are created new energy systems based on the undeniable advantages of fossil fuels: high concentration, possibility of stocking, possibility of transportation over the long distances and transformation into energy – heat, mechanic, electricity. During over 200 years the humanity has created an enormous energy sector, which ensures fundamental services: lighting, heating, refrigeration, transportation, technological processes, etc. Without energy there cannot be maintained modern standards of life, wealth, education and health, but at the same time it has been recognized that modern energy is "responsible" for different environmental issues. The humanity should find a compromise between the increasing demand of energy services and the acute necessity to protect the environment [4-5].

2. Promotion of clean technologies in the context of sustainable development

Sustainable development means greater importance than in the past to the environment quality and general services offered by natural environment.

The environment functions are considered the main objectives in the concept of sustainable development. They have contributions, directly and indirectly, to the quality of life, to the GDP through the environmental sector, to the economic activity through the raw materials and energy input and to the systems of life support, [6].

Natural environment has three major functions that have a direct significance to the interpretation of the sustainable development concept:

- Direct use for individuals.
- Supplying the inputs for economic processes.
- Ensuring services for life support.

The investments for environmental protection and comfort create revenue and jobs. The investments in the environment sector are less productive, leading to slower economic development [7-8].

Environmental related programs contribute to the increase of GDP in the first year, but the effect in the final year can be positive or negative.

The compatibility of the economic growth with the environmental quality is a controversial issue. Thus, for a long period of time two antagonist currents have confronted:

A. The anti-growth current that says:
   - The economic growth inevitably leads to the environment degradation due to the fact that it shall use an increased quantity of raw materials and energy that leads to increased quantity of wastes.
   - The increased quantity of wastes endangers exhaustion of resources but also the circuit of wastes, which can overcome the environment capacity of their assimilation.

B. The pro-growth current with concepts:
   - The economic growth is the only tool that can be used to generate funds for environmental protection.
   - Huge investments in the environmental protection sector restrict the growth, damage international competition and reduce jobs.

In the last years respecting the regulations and legislation regarding environmental protection is an integral part of strategies of industrial companies. These are transposed through restrictions in operation, significant investments operation costs.

Due to physical and chemical characteristics of emissions resulted from different industrial sectors (when operating normally) cannot be higher than specific limits imposed by regulations, there are necessary **supplementary investments and operation costs** for specific equipment for industrial units.

There are also necessary supplementary measures for treatment and elimination of wastes resulted from the industrial processes.

The global strategy of companies should take into consideration restrictions imposed due to environmental protection, the probability of accidents during operation, which can have significant impact over the environment. There should also be anticipated the evolution of regulation because the values for pollutant emissions regulated by laws at a certain moment can in future draw **eco-tax payment** [9-10].

Due to this fact the adoption of clean technologies and eco-products reduces the incidence of industrial activity over the environment through pollution prevention at the production and consumption levels. These are priority objectives in the new strategies for companies' development.

The first definitions of **clean techniques or technologies** have been formulated in 1970: technologies that **"produce better" leading to a "lower pollution"**. These technologies are an integral part of the production and are radically different from the technologies meant to de-pollute.

The official adopted term is **clean technology** and normally used for delimitating industrial processes with several technologies. There are also used terms of **clean technique and clean process**. Taking into consideration the objective of limiting the wastes generation through application of these technologies, there are also used the following terms: **technology with reduced quantity of wastes** or **technology without wastes**.

The clean technologies, according to official (1979) definition, there are included those **"technologies that allow recycling of water or pollutants, that can or cannot be wastes or that allow reuse of pollutants as secondary raw materials"**, [11].

The main **objectives** (set at EU level), which should meet the clean technologies are:

- Reduced consumption of raw materials.
- Reduced consumption of energy.
- Reduced generation of pollutant emissions and wastes.

Thus, **the interest** for applying these types of technologies is of environmental, energy and economic order.

The main aim of applying these technologies in different industrial sectors is to:

- Reduce pollution.
- Reduce consumption of raw materials.
- Increase energy efficiency of the process.

Besides the main advantages, mentioned above, the applying of clean technologies leads also to:

- Increasing the quality of the products.
- Improving the working conditions.
- Improving the company's image.
- Decreasing the possibility of accidents.

All these advantages have and economic and social impact within the technological process where there has been implemented a clean technology [12].

Tables 1 and 2 present the results of environmental and energy balances made after applying of over 600 clean technologies (compared to classic technologies which are replaced), [13-15].

Table 1. Results of applying clean technologies

Quantification of effects of implementation of clean technologies	*Value (%)*
Pollution reduction • in water • in air	 95 5
Savings at the consumption level: • water • raw materials • energy	 65 67 8
Wastes recycling	26
Reduction of accidents' risk	21
Improving working conditions	20

Table 2. Ecological results of applying different types of clean technologies compared with classic technologies that are replaced

Results – year 2000		*Results - year 2010*	
Type of process	*Environmental impact reduction*	*Type of process*	*Environmental impact reduction*
Control of existing technologic processes	25 %	Control of existing technologic processes	37 %
Partial modification	42 %	Partial modification	31 %
Total modification	33 %	Total modification	42 %

Those three ways of applying clean technologies (compared to classic procedure) can be synthesised as follows:

a) Controlling the existing technological processes (stage 1).
b) Partial modification of existing technological processes (stage 2).
c) Total modification of existing technological processes (stage 3).

From the economic point of view the third option is justifiable generally in particular cases: companies with old technologies. These companies, whose economic activity is not feasible, should change the old technologies and with this occasion can adopt new processes based on clean technologies.

Application of clean technologies implies installation of the following equipment: measurement and control devices, recycling equipment or integral change of technology, as function of those three stages applied. Compared with de-pollute technologies application of clean technologies has higher efficiency in terms of environmental protection due to the fact that it acts directly at the sources of possible pollution and also due to higher energy and economic efficiency, [17-18].

3. Case study – Implementation of a clean technology (stage 2 – partial modification of an existing process)

3.1. Presentation of the case study

A thermal treatment furnace, for mechanically processed pieces, which uses as fuel natural gas, was initially designed without regenerative air pre-heater. The furnace characteristics are: useful capacity q_u = 10 MW, heat losses q_p = 1 MW. The temperature of flue gasses at the exit from the furnace is t_g = 1000 °C. The installation of an air pre-heater for the furnace, which heats up the combustion air up to 250 °C, involves an investment of 210,000 €. The fuel used has the following characteristics: lower heating value H_i = 36 MJ/Nm^3; theoretical volume of combustion air, v_a = 12.5 Nm^3/Nm^3; theoretical volume of flue gasses v_g = 13.5 Nm^3/Nm^3.

The comparative energy, environmental and economic analysis is performed for the two cases of furnace operation:

a) Before modifying the existing technology.
b) After partial modification of the existing technology through recuperation of heat from flue gasses for pre-heating combustion air.

Initial data taking into consideration:

- t_a, t_B – temperature of cold air, respectively of fuel introduced into the furnace.
- t_g – temperature of flue gasses at the exit from the furnace.
- c_g = 1.5 kJ/ Nm^{3}K, represents specific heat of flue gasses.
- t_{ap} – temperature of pre-heated air.

- t_{gev} – temperature of flue gasses at the exit from air pre-heater.
- c_a = 1.31 kJ/ Nm^3K, represents specific heat of pre-heated air.
- The operation period of the furnace, τ = 4,500 hours/year.
- Fuel price, natural gas, p_B = 25 €/MWh.
- There is a simplified hypothesis: the temperatures of air and fuel introduced into the furnace are equal: $t_{ar} = t_B = 0$ °C.

3.2. Analysis of the opportunity of implementation of clean technology

Table 3 presents the results of the complex analysis for justifying the opportunity of implementation of clean technology – partial modification of the technological process.

Table 3. Analysis of the opportunity of implementation of a clean technology

Energy indicator	*Indicator calculation*
B_a – fuel consumption of the furnace before modification of the technology	$B_a = \frac{q_u + q_p}{H_i - v_g \cdot c_g \cdot t_g} = \frac{11}{36 - 20.2} = 0.698 \frac{Nm^3}{s}$
W_a – fuel energy introduced into the furnace before modification of the technology	$W_a = B_a \cdot H_i \cdot \tau \cong 112{,}500$ MWh/year
B_b – fuel consumption of the furnace after technology modification	$B_b = \frac{q_u + q_p}{H_i + v_a \cdot c_a \cdot t_{ap} - v_g \cdot c_g \cdot t_g} = 0.554 \frac{Nm^3}{s}$
W_b – fuel energy introduced into the furnace after modification of the technology	$W_b = B_b \cdot H_i \cdot \tau \cong 90{,}000$ MWh/year
ΔW – annual absolute energy savings	$\Delta W = W_a - W_a = 22{,}500 MWh/year$
Δw – relative energy savings	$\Delta w = (W_a - W_b)/ W_a = 20$ %
ΔC – annual financial savings	$\Delta C = 5 \cdot 4{,}500 \cdot 25 = 562{,}500$ €
DRB – payback period	$DRB = \Delta I / \Delta C = 0.91$ years
ΔM_{CO2}/an –CO_2 emissions reduction compared to reference solution	$\Delta M_{CO2} = M_{aCO2} - M_{bCO2} = 934.6$ t/year
ΔERN – reduction of contribution to the exhaustion of the natural reserves	$\Delta ERN = \Delta B/a = 44{,}696\ Nm^3/year$ a=50 years
ΔGWP – reduction of the green house effect	$\Delta GWP = \Sigma_i\ (GWP_i * \Delta m_i) = 1{,}240$ tCO_2/year GWP CO_2 = 1 GWP CH_4 = 35

3.3. Conclusions regarding the case study and results analysis

Quantification of the energy efficiency of recuperation is performed using fuel savings reached through pre-heating of combustion air.

For quantification of the economic efficiency of the proposed solution there has been calculated the simple payback period.

The simple payback period is lower than 5 years, which is the reference for energy efficiency projects; thus, the recuperation solution applied is feasible from the economic point of view. Quantification of the environmental efficiency of recuperation is performed through using different indicators, shown in Table 3.

Quantification of the energy, economic and environmental efficiencies of the project regarding the implementation of a recuperation of heat from flue gasses for combustion air pre-heating leads to the conclusion of implementation of this solution, due to the fact that there are energy savings, financial savings and environmental pollution reduction. The economic efficiency is well quantified through the simple payback period, which is lower than 5 years; the reference for energy efficiency projects, [18-20].

Conclusions

The European Council has adopted in June 2010 the energy strategy: ***"Europe 2020 for an intelligent, sustainable and favourable to inclusion growth"***. The objectives established are ambitious concerning energy aspects but also concerning environmental protection, taking into consideration climate changes occurring today, [21].

Thus, the priorities of the European strategy are as follows:

- Reduction with 20 % of GHG emissions.
- Increasing at 20 % of renewable energy production from the total.
- Decreasing the final energy consumption with 20 %.

For a long term period , up to 2050, the energy objectives correlated with environmental objectives are very ambitious, especially for the energy sector, which together with transports are the main responsible the pollutant emissions; these objectives cannot be reached without implementation of different technologies for carbon capture and storage.

Along with EU Member States (which are responsible of about 16 % of CO_2 generation) there should team up states as USA, Canada, China, India and South Africa, taking into account that the last three are the "most responsible' for GHG generation.

In Romania for correct implementation of the energy-climate change package there should be considered the following:

- Elaboration of a correlated national strategy concerning renewable energies and taking into consideration the targets that Romania has assumed for the period 2013-2020.
- The national authorities should be prepared for promotion, support and implementation and following up different energy programs.
- It is necessary to create the legal framework for ensuring the funds for investments coming from CO_2 certificates valorisation on the EU market and from other financial sources.
- Development on the national level of different education and qualification programs linked to energy sector and energy efficiency.
- Ensuring of a legal framework, simple and efficient, that will allow implementation on the Romanian market of different clean technologies.

Among the strategic objectives of Romania in the field of energy there are the following:

- Increasing energy efficiency.
- Promotion of energy production from renewable energy sources
- Rational and efficient use of primary energy resources.

The complexity of problems regarding energy sector of the entire chain (production, transportation, distribution and final consumption) has grown lately once the environmental issues, climate change and exhaustion of natural reserves persisted. In this context the main objective of international cooperation in the energy and environmental fields is sustainable development.

Sustainable development places the environment in the centre of attention within the concept. The environment functions are considered as being the primary objectives, they having direct and indirect contributions to the quality of life and growth of the GDP.

Through sustainable development there should be understood a process of economic development that will have as a result increasing the quality of life without deteriorating the ecosystem of the Planet.

This means a well-ordered use of natural resources so each individual has its own part of clean environment, as well as the obligation of trying to improve it for ensuring for our children a better chance.

The sustainable energy policy maximises the human wealth for a long term period, simultaneously with keeping a dynamic equilibrium between safety of energy supply, competitiveness of energy services and environment protection.

The legal framework in the field of environmental protection has the main objectives prevention and reduction of pollution of any kind, conservation and keeping the quality of environment factors, responsible use of natural resources, ecologic reconstruction of affected areas and keeping the equilibrium between environment and quality of life.

In conclusion, the future belongs to promotion of sustainable energy, acting directly upon the fields such as: evaluation of environment protection policies, elaboration of scenarios for energy sector correlated with environment protection, new energy resources and technologies, access to energy in urban areas, global legal framework correlated with regulations regarding energy commerce and elaboration of best practices codes.

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