www.ees.uni.opole.pl

ISSN paper version 1642-2597
ISSN electronic version 2081-8319

Economic and Environmental Studies
Vol. 18, No 1 (45/2018), 375-386, March 2018

The importance of modernizations in realization of sustainable development principles – a case study of the Heating Plant 'Piast' in Bieruń, Poland

Anna SZWEDA

Krakow University of Economics, Poland

Abstract: The issue of environment protection has gained in importance recently in connection with progressive environmental decay, which is caused by a steady economic development and exploitative natural resource management. Energetics is one of the industries, which have a damaging influence on the environment, especially in the matter of air quality. Polish energetics is based on carbon-intensive fuels due to big coal reserves commanded by the country. Coal burning leads to air pollution emission of sulfur dioxide, carbon dioxide and particulate matter. Modernizations of power installations are one of the ways towards realization of sustainable development principles. The article is devoted to modernizations implemented in the Heating Plant 'Piast' based in Bieruń, Poland. The investments embraced modernizations of the heating boilers and gas-cleaning plants, which constitute the IPPC installations. The author presents research results concerning the influence of conducted modernizations on the amounts of air pollution emissions.

Keywords: sustainable development, environment protection, energetics, heating plant, modernizations of power installations, air pollution emission, air quality

JEL codes: Q1, Q4

https://doi.org/10.25167/ees.2018.45.21

Correspondence Address: Anna Szweda, Wydział Towaroznawstwa, Uniwersytet Ekonomiczny w Krakowie, ul. Rakowicka 27, 31-510 Kraków, Polsk

E-mail: annaszweda@onet.eu

1. Introduction

Over the last years environmentally oriented tendencies have been developing, especially those related to air quality improvement. Power industry is one of the branches which have a damaging influence on the environment, particularly in the matter of air quality. This sector generates significant amounts of substances, which pollute the air. More and more emphasis is laid on minimizing the negative influence on the environment caused by burning coal to generate heat, and applying environmentally-friendly technologies in power industry.

The issue of environment protection has gained in importance recently, which results in creating many regulations and laws. The matter of environment quality and protection was pointed out because of progressive environment decay caused by steady economic development and exploitative natural resource management.

The crucial event regarding the development of pro-environmental activities, was the United Nations Conference on the Human Environment, which took place in Stockholm, Sweden, in 1972. It was the first time the term 'sustainable development' had been used in relation to human environment quality improvement, including economic, ecological and social issues (Wyrwa et al., 2012: 18). As a result, the Declaration of the United Nations Conference on the Human Environment, also called the Stockholm Declaration, was accepted. It classified environment protection as a major aim of each country's policy, and emphasized the significance of international cooperation in this field.

Sustainable development was defined as a process, which "meets the needs of the present without compromising the ability of future generations to meet their own needs" (UNESCO, 2017). In the ecological sense, the concept of sustainable development refers to conservation of the environment for future generations towards its holistic protection, including all of its components.

The goal of the paper is to prove that the idea of sustainable development can be fulfilled even in such a contaminative sector as power industry based on hard coal is. The ecological effects of modernizations conducted in the Heating Plant 'Piast' in Bieruń will be presented.

2. Air pollution

Supreme Audit Office's reports show that Poland, in the period between the year 2008 and the first half of the year 2014, was not even close to the European Union air quality

standards, and is one of the countries with the most polluted air. Instances of the highest excess were noted in the case of particulate matter – PM 10 and PM 2.5, and benzo(a)pyrene. These substances are toxic and dangerous for health. High PM 10 concentration is caused by the so-called low emission, which includes domestic heating stoves emissions and local heating plants emissions, where coal is burned in a non-effective way. The amendment to environmental law, also called 'anti-smog law', was implemented in 2015. By virtue of this law, local authorities gained new competences in the field of setting emission, technical and quality standards for fuel burning appliances in the local area (Różański, 2016: 28-29).

Acid rains and greenhouse effect are caused by high levels of air pollution. A low amount of SO_2 and NO_x occurs in the environment from natural sources, for example volcanic eruptions (US EPA, 2016). However, a large amount of the compounds is emitted into the atmosphere as a result of burning of fossil fuels. SO_2 and NO_x react with water, oxygen and other substances, whereby nitric acid and sulphuric acid are formed. This is how acid rains are made. They appear as precipitations, which contain acid components. Greenhouse gases occur in the atmosphere both, naturally and as a result of human activities. They absorb infrared radiation, which prevents it from emerging outside the earth's atmosphere. Temperature is increasing as a result. They lead to the greenhouse effect, which is regarded as a cause of global warming. CO_2, methane, N_2O, CFCs and water vapor count as greenhouse gases (US EPA, 2016). Acid rains and greenhouse effect threaten the environment and human health.

EU ETS (European Union Emissions Trading System) constitutes a tool to limit greenhouse gases emissions, especially CO_2. This system is a part of climate package, which aims to prevent climate change. EU ETS is based on assigning certain amount of allowances for greenhouse gases emissions to factories, power stations, and other installations with a net heat excess of 20 MW. In the case of exceeding the limit, the installation is obligated to purchase allowances from others or pay a fine. This system encourages enterprises to cut down on emissions.

3. Energetics in Poland

Polish energetics is based on carbon-intensive fuels due to big coal reserves commanded by the country. Carbon-intensive fuels include hard coal and brown coal. Figure 1. shows the structure of usage of fuels which are used in heat production.

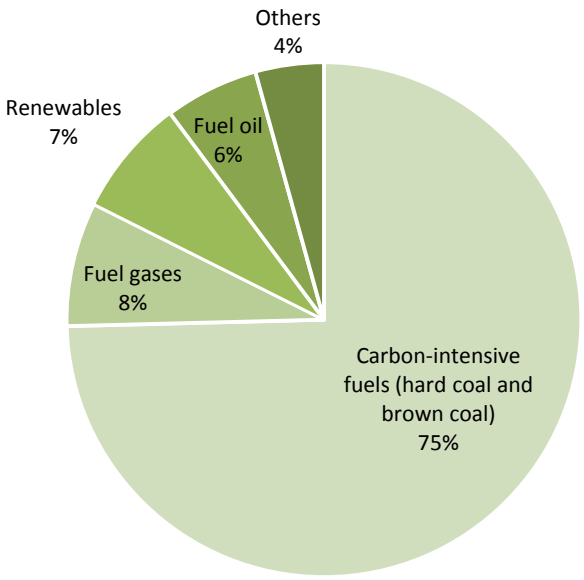

Figure 1. The structure of usage of fuels used to heat production in 2015

Source: Author's own elaboration based on: Raport Prezesa URE – Energetyka cieplna w liczbach – 2015, 2016:13

Coal is the high emission primary energy carrier. The process of coal burning, which aims to generate heat energy, causes emissions of substances such as:

- carbon oxides (CO, CO_2), which are the effect of element C burning,
- sulphur oxides (SO_2, SO_3) caused by sulphur burning,
- nitrogen oxides (NO, NO_2, N_2O) due to nitrogen in the air, where coal is burned,
- water vapor (H_2O) as the effect of burning and evaporating of moisture contained in coal,
- particulates (ash, carbon black, trace elements), which are contained in mineral substance of coal.

The coal burning products are also combustion wastes, such as ashes and slag (Gawlik, 2011: 46-47).

Energy industry is one of the major sources of pollutants which come from the type and amount of emitted substances (Nadziakiewicz, 2005: 69). It is necessary to take actions in the field of minimizing emissions of adverse substances in the process of coal burning to meet stricter and stricter European Union's requirements. A decrease in the amount of emitted CO_2, which has a negative influence on air quality and is considered the main cause of climate changes, requires enhancement of effectiveness of primary energy carriers usage and investments in energy-efficient combustion facilities. Taking investments in low emission

technologies for heat generation, for example clean coal technologies, is the matter of utmost importance in order to reduce the negative environmental impact of the energy industry, especially in the case of air quality (Stańczyk et al., 2012: 168).

The term 'clean coal technologies' implies all processes and ways of using carbon, which aim to minimize the negative influence of products of its burning on the environment (Instytut Energetyki, 2012). Those technologies embrace both coal yield, its exploitation and waste management. Clean coal technologies embrace, among others, processes of flue gas scrubbing, which is accomplished through dust extraction, de-sulphurization, reduction of nitrogen oxides and carbon capture and storage (CCS).

4. 4. Characteristics of the Heating Plant 'Piast'

The Heating Plant 'Piast' is situated in the Hard Coal Mine 'Piast" area, in Bieruń. The plant is managed by *Węglokoks Energia NSE*. The heating plant carries out processes of chemical transformation of coal into thermal energy of heating water through burning the fuel. The coverage of the plant involves heat generating, transmission and distribution for the use of hard coal mine, mining district along with schools, day care center, health center, housing estate and companies situated in Bieruń (Pozwolenie zintegrowane…, 2016).

The Heating Plant 'Piast' uses an IPPC installation of coal combustion, which includes:

- stoker-fired water boilers, hard coal-fired, type WR,
- de-dusting installation and machinery (including cyclone separators and electrostatic precipitator).

The coal combustion installation embraces four boilers:

- heating boiler WR-5/1,
- two heating boilers WR-10: WR-10/2 and WR-10/3,
- heating boiler WRm-30/6.

The heating boiler WR-5/1 is a two-pass construction. It is equipped with a mechanical stoker.

The grate furnace fulfills the following functions:

- steady and fluent fuel feed according to loadings of the boiler,
- temperature control,
- air feed necessary for complete combustion (Kruczek, 2001: 85-86).

The heating boilers WR-10/2 and WR-10/3 are two-pass built. The first part of the construction is a completely shielded furnace chamber, and the second part consists of three heating surfaces. Both boilers are equipped with a mechanical stoker and air blowing control in each zone.

The heating boiler WRm-30/6 is a three-pass construction. There are shields of furnace chamber in the first pass. The second one consists of heating surface, which is divided into four parts separated from each other by intermediate chambers. An additional water heater, which is shielded in every side of the boiler, constitutes the third pass. The boiler is equipped with a double mechanical stoker and air blowing control in each zone.

There are many pro-ecological efforts taken in the field of air protection in the Heating Plant 'Piast', including:

- equipping coal boilers in individual dust exhausters: pre-de-dusters and sack filters or an electrostatic precipitator,
- shielding of desulphurization plants by the semi-dry ammoniac method with reagent De-emis,
- monitoring of combustion parameters,
- activities leading to improvement of the energy balance of the heating plant (Pozwolenie zintegrowane…, 2016).

The de-dusting installations of the heating boilers WR-5/1 and both WR-10s consist of multicyclones, which conduct pre-de-dusting, sack filters responsible for de-dusting and exhaust fans, which carry out exhaust gases to the de-dusting system.

The cyclonic precipitators are responsible for pre-de-dusting. They are used to dust extraction of gases containing particulates, whose diameters exceed 10 μm. The cyclones functioning is based on using centrifugal force. Gas is carried contiguously to the cylindrical part of the cyclone, which causes its rotary motion. Particulates contained in exhaust gases are pushed to the cyclone wall, wherefrom they slip to the dust container (Nadziakiewicz, 2005: 87-88). The effectiveness of de-dusting is higher, when the cyclone's diameter is smaller, thus multicyclones are widely used. They are composed of several or several dozen smaller diameter cyclones (Cęckiewicz and Szczepanik, 2006: 28).

Sack filters are used in de-dusting, because of their high effectiveness in dust extraction of particles with a diameter exceeding 1 μm. Dust separation is conducted by sacks made of selected filtering nonwoven fabric. Exhaust gases flow inwards the sacks, where particulates settle on the surface, whereas refined gas is carried out to the clean gas chamber. It is necessary

to regenerate filtering material regularly through insufflating clean and drained air inwards clean sack (Nadziakiewicz, 2015: 91).

In the case of the heating boiler WRm-30/6 the pre-de-dusting was skipped, and de-dusting is fulfilled by an electrofilter. It uses electrostatic forces. The functioning of an electrostatic precipitator is based on electrostatic particles charging, charged particles eduction from electric field and removing dust particles from eduction surface (Cęckiewicz and Szczepanik, 2006:29). The process is carried out with the collecting electrode to which charged particles are pulled up. The electrodes are regularly shaken to scrub them and cause a descent of dust to the bottom of the filter chamber (Nadziakiewicz, 2005:88).

5. 5. Modernizations conducted in the Heating Plant 'Piast'

In 2011, shielding and trial run of the de-sulphurizing plants of all the heating boilers in the heating plant was completed. The semi-dry ammoniac method with reagent De-emis is applied to desulphurize exhaust gases. This modernization aimed to reduce the concentration of SO_2 in emitted combustion gases so as not to exceed stated emission standards, even when high sulphur content coal (over 1.2%) is used. Effectiveness of desulphurization depends on two factors – quality of coal and amount of atomized reagent De-emis.

Technology of exhaust gases desulphurization by the semi-dry ammoniac method is based on atomizing reagent directly to the gases. The atomizing can be held in two places – in the case of the heating boilers WR-5/1, WR-10/2 and WR-10/3 in boilers spaces, where the temperature amounts to 400°C or in gas ducts of the heating boiler WRm-30/6, where the temperature exceeds 110°C. Reagent De-emis is a mixture of approximately 24% solution of ammonium hydroxide and a catalytic booster containing stabilized hydroperoxide and iron compounds. High temperature and chemical reaction of hydroperoxide and transition metals cause a break down of O-O bond in hydroperoxide molecule (H_2O_2), and free radicals are formed. Free radicals typify the capability of accelerating reaction rate and feature of their multiple usage in chemical reactions, which help to reduce the amount of consuming ammonium hydroxide in the process (Omega, 2016).

The process of de-dusting is carried out by using plants equipping the heating boilers – sack filters in the case of the heating boilers WR-5/1, WR-10/2 and WR-10/3, and an electrostatic precipitator in the heating boiler WRm-30/6.

In 2011, modernization of the dust extraction plant of the heating boiler WR-5/1 was realized by virtue of its poor technical condition. The foregoing concentrators and cyclone batteries were superseded by a sack filter, Flat Bag type, with concentrator MOS (multicyclone). Investments in modernizations of the de-dusting plant and opening of a desulphurization plant contribute to dust concentration reduction to the level of 20-30 mg/m^3_u in conversion to content of O_2 in 6% exhaust gases.

Modernization of the heating boiler WR-10/2 and its dust extraction plant was finished in 2012. The foregoing precipitator was superseded by a multicyclone with a sack filter. A new exhauster and new exhaust gas ducts were shielded. The investment included among others:

- shielding of the sidewall of a furnace chamber,
- adjustment of the heating surface in the second pass,
- shielding of the electromagnetic mallets, which scrub the heating surface inside the water heater,
- shielding of the water heater in the third pass,
- replacing fixture, pipe works, masonry envelope and insulation,
- installation of new measurement and control equipment (Dokumenty wewnętrzne firmy Węglokoks Energia).

On account of those modernizations the heating boiler effectiveness exceeding 82% was reached. Higher effectiveness leads to a decrease in usage of coal and amount of emitted pollutions. Acceptance measurements, which were carried out while desulphurization plant was also operating, showed dust concentration reduction to the level of 36-58 mg/m^3_u in conversion to the content of O_2 in 6% exhaust gases.

Modernization of the heating boiler WR-10/3 and its de-dusting installation was conducted in 2013. The investment embraced:

- modernization of the furnace chamber shields,
- modernization of the shields in the second pass,
- shielding of the economizer,
- shielding of the electromagnetic mallets which scrub the heating surface inside the water heater,
- replacing fixture, pipe works, masonry envelope and insulation,
- installation of new measurement and control equipment (Dokumenty wewnętrzne firmy Węglokoks Energia).

As a result, the heating boiler effectiveness increased to the level of 83%, hence the amount of used coal and emitted pollutions was reduced. The acceptance measurements, which were carried out while desulphurization plant was also operating, showed dust concentration reduction to the level of 36-75 mg/m^3_u in conversion to the content of O_2 in 6% exhaust gases.

In 2014, the measurement and control equipment and dust extraction plant of the heating boiler WRm-30/6 were modernized. The refurbishment included modernization of the electrostatic precipitator and the electric part of the heating boiler, and installation of new instrumentation and automatics. Due to those modernizations and cooperation with the desulphurization plant, dust concentration reduction to the level of 74.8 mg/m^3_u in conversion to the content of O_2 in 6% exhaust gases was reached.

Modernizations of the heating boilers with their de-dusting and desulphurization plants have resulted in reduction of the amount of emitted CO_2 indirectly. They caused a decrease in using coal, hence in the amount of pollution. The other crucial factor influencing CO_2 emission is the type of combusting fuel. Hard coal quality depends on the calorific value, the degree of coalification and the content of sulphur and ash. The calorific value determines how many energy units are generated as a result of coal combustion expressed in mass unit. The degree of coalification is expressed in the content of element C in coal, and the quality of coal rises commensurately with the rise in the element C content.

6. Effectiveness of the investments

In order to prove the effectiveness of the investments carried out in the Heating Plant 'Piast' in the field of minimization of pollutants emitted as a result of the combustion process, the data concerning energy production output and amount of emitted CO_2, SO_2 and particulates, in the unit of megagrams [Mg], were correlated. Based on this data, CO_2, SO_2 and particulates emission indicators were calculated in conversion to 1 GJ (Gigajoule) of the generated energy. The research took into account the period from 2011 to 2015. The results are shown in the tables below.

Table 1. Energy production output [GJ] in the period from 2011 to 2015

2011	2012	2013	2014	2015
268972.1	283041.3	272953.3	236507.0	239568.0

Source: Internal documentation of Węglokoks Energia

Table 2. Amount of CO_2, SO_2 and particulates emissions [Mg] in the period from 2011 to 2015

	2011	2012	2013	2014	2015
CO_2	31963	31527	29290	25640	25198
SO_2	227.60875	194.48998	164.28727	112.47128	119.57107
particulates	0.00013918	0.00010218	0.00004787	0.00002315	0.00002599

Source: Author's own elaboration based on: Internal documentation Węglokoks Energia

Table 3. CO_2, SO_2 and particulates emissions indicators [Mg/GJ] in the period 2011-2015

	2011	2012	2013	2014	2015
CO_2	0.11883	0.11139	0.10731	0.10841	0.10518
SO_2	0.00084622	0.00068714	0.00060189	0.00047555	0.00049911
particulates	0.00013918	0.00010218	0.00004787	0.00002315	0.00002599

Source: Author's own elaboration based on: Internal documentation of Węglokoks Energia

As a result of the modernizations carried out in the heating plant, the amount of emitted pollutants was reduced. The results present themselves as follows:

- the amount of emitted CO_2 in conversion to production unit decreased and in 2015 was lower by 11.5% than in 2011,
- the amount of emitted SO_2 in conversion to production unit decreased and in 2015 was lower by 41.0% than in 2011,
- the amount of emitted particulates in conversion to production unit decreased and in 2015 was lower by 81.3% than in 2011.

The results show explicitly that the conducted and previously characterized modernizations of the heating boilers, de-dusting and desulphurization plants had the desired effects in terms of air quality improvement in the subsequent years.

7. Conclusion

Energetics is one of the industries, which exert a damaging influence on the environment, especially in the matter of air quality. The process of generating energy through coal combustion causes emissions of many pollutants, including SO_2, CO_2 and particulates. The air quality deteriorates because of pollution, thus taking pro-ecological investments is

crucial to preserve the environment for future generations, according to the idea of sustainable development.

In order to minimize the negative impact on the environment, especially on the air quality, numerous modernizations were carried out in the Heating Plant 'Piast'. The investments embraced modernizations of the heating boilers WR-5/1, WR-10/2, WR-10/3 and WRm-30/6, desulphurization and de-dusting plants, including the IPPC installation. Based on the comparative analysis of the energy production output and the amount of emitted CO_2, SO_2 and particulates, the author came to the conclusion that the abovementioned investments have contributed to a reduction in the pollutant emissions and to improvement of the air quality.

Literature

Cęckiewicz, S.; Szczapanik, A. (2006). *Oczyszczanie gazów odlotowych, spalinowych i powietrza.* Kraków: Ośrodek Vadawczo-Rozwojowy Budowy Urządzeń Chemicznych CEBEA.

Gawlik, L. (2011). *Steam coal. Perspectives of development in the light of environmental priorities.* Kraków: Instytut Gospodarki Surowcami Mineralnymi i Energią PAN - Wydawnictwo.

Instytut Energetyki (2012). *Czyste technologie węglowe.* Available at: https://www.ien.com.pl/czyste-technologie-weglowe.

Accessed 22 June 2017.

Internal documentation of Węglokoks Energia.

Kruczek, S. (2001). *Kotły. Konstrukcje i obliczenia.* Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej.

Nadziakiewicz, J. (2005). *Źródła zanieczyszczenia powietrza i metody oczyszczania gazów z zanieczyszczeń pyłowych i gazowych.* Bytom: Wyższa Szkoła Ekonomii i Administracji.

Omega (2016). *Odsiarczanie gazów spalinowych.* Available at:
http://eomega.eu/odsiarczanie-gazow-spalinowych/.

Accessed 22 June 2017.

Pozwolenie zintegrowane udzielone Węglokoks Energia NSE sp. z o. o. dla instalacji spalania paliw o mocy nominalnej powyżej 50 MWt eksploatowanej w Bieruniu, przy ul. Granitowej 16 (2016).

Raport Prezesa URE (2016). *Energetyka cieplna w liczbach – 2015.* Available at: https://www.ure.gov.pl/pl/wskazniki-dane-i-anali/sprawozdania-raporty-pr. Accessed 22 June 2017.

Różański, E. (2016). Węgiel przyjazny środowisku. *Magazyn Korporacyjny Grupa Kapitałowa Węglokoks* 04(16).

Stańczyk, K. et al. (2012). The potential of the air-blown underground coal gasification product gas utilization in the fuel and energy sector in the light of national and European research. *Development of coal, biomass and wastes gasification technologies with particular interest in chemical sequestration of CO_2.* Kraków: AKNET.

UNESCO (2017). *UNESCO a zrównoważony rozwój.* Available at: http://www.unesco.pl/edukacja/dekada-edukacji-nt-zrownowazonego-rozwoju/unesco-a-zrownowazony-rozwoj/. Accessed 22 June 2017.

US EPA (2016). *What is Acid Rain?* Available at:https://www.epa.gov/acidrain/what-acid-rain. Accessed 22 June 2017.

Wyrwa, A.; Krawczyk, J.; Guła, A. (2012). Strategy and law regulations of European Community regarding production, emission and sequestration of CO_2 in fuel and power sector. *Development of coal, biomass and wastes gasification technologies with particular interest in chemical sequestration of CO_2*. Kraków: AKNET.

ZNACZENIE MODERNIZACJI W REALIZACJI ZASAD ZRÓWNOWAŻONEGO ROZWOJU – NA PRZYKŁADZIE ZAKŁADU CIEPŁOWNICZEGO „PIAST" W BIERUNIU

Streszczenie

W związku z postępującą degradacją środowiska naturalnego, spowodowaną dynamicznym rozwojem gospodarczym oraz prowadzeniem rabunkowej gospodarki zasobami naturalnymi, kwestie związane z szeroko pojętą ochroną środowiska zyskały na znaczeniu. Energetyka stanowi jeden z najbardziej obciążających środowisko naturalne sektorów przemysłowych, w szczególności zaś w odniesieniu do jakości powietrza. Polski przemysł energetyczny opiera się głównie na paliwach węglowych, co spowodowane jest znaczną ilością posiadanych zasobów węgla. Instalacje energetycznego spalania węgla powodują emisje zanieczyszczeń, takich jak dwutlenek siarki, dwutlenek węgla oraz pyły. Zasady zrównoważonego rozwoju realizowane są m. in. na drodze modernizacji instalacji energetycznych.

Niniejszy artykuł opisuje modernizacje instalacji energetycznego spalania węgla przeprowadzone w Zakładzie Ciepłowniczym „Piast" w Bieruniu. Podjęte działania inwestycyjne objęły modernizacje wszystkich kotłów oraz instalacji odpylania i odsiarczania spalin, składających się na instalację IPPC. Przedstawione modernizacje zestawione zostały z wielkościami emitowanych zanieczyszczeń w wybranym okresie badawczym.

Słowa kluczowe: zrównoważony rozwój, ochrona środowiska, energetyka, zakład ciepłowniczy, modernizacje instalacji spalania węgla, emisja zanieczyszczeń, jakość powietrza.

Kody JEL: Q1, Q4

https://doi.org/10.25167/ees.2018.45.21