

**THE ASSESSMENT OF COAL'S CONTRIBUTION
TO ENVIRONMENTALLY SUSTAINABLE ENERGY
DEVELOPMENT IN POLAND**

Submitted by

Magdalena Mateuszczyk

**A thesis to be submitted to the Faculty of Graduate Studies in Partial Fulfillment of
the Requirements for the Degree**

Master of Natural Resources Management

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Of Master of Natural Resources Management (M.N.R.M)

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Abstract

The thesis analyzes the possibility of coal's contribution to environmentally sustainable resource development in Poland and identifies the ways to enhance the said contribution. The objectives are: 1) to identify the main environmental impacts of coal as an energy source in Poland; 2) to describe existing Polish laws and related EU laws and regulations aimed at ensuring coal use is sustainable; 3) to establish target issues for making coal use more environmentally sustainable; and 4) to examine how technological or other improvements can contribute to improving the environmental sustainability of target issues. The objectives were addressed primarily through open-ended interviews with coal experts, extensive review of the literature, field observations, and attending the relevant meetings and conferences.

The research outcomes show that hard-coal will remain the key energy source in Poland for at least the next 20 years, because other energy sources are insignificant while resources of coal are relatively high. Today coal is often not considered as a part of the sustainable energy development due to its large negative impact on the environment. To create environmentally sustainable energy system based on coal, Poland has to undertake the steps to minimize its impact on the environment. The most important problem to be solved is the reduction of greenhouse gas emissions. Reduction of pollutants emission was expressed in a number of international agreements, conventions and protocols (e.g. Climatic Convention, Kyoto Protocol, etc.), some of which were signed and ratified by the Polish government. This resulted also in establishing the limits for pollutants emission (nitrogen oxides, carbon oxides, etc.). In order to achieve emissions reductions

and to increase coal's contribution to environmentally sustainable energy use in Poland it is necessary to apply advanced clean coal technologies and provide appropriate legislative and policy changes.

This thesis presents an outline of problems related to hard-coal usage for clean energy production in Poland, the current regulatory environment in Poland and EU supporting the initiatives improving environmental performance of coal, as well as the assessment of technological solutions which may help to reduce emissions associated with coal use.

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Glossary of Terms

CHP – Combined Heat and Power

Coal sector – covers coal mining and industry that consume large quantity of coal for energy production

Coking coal - the most important of the bituminous coals, which burns with a long yellow flame and creates an intense heat when properly attended. It is usually soft. Coking coal is used as a fuel and as a reducing agent in smelting iron ore in a blast furnace (Energy Information Administration, 2007)

Derogation – in the EU legislation means that a member state delays the implementation of an element of an EU Regulation into its legal system over a given timescale.

EU-15 - refers to the 15 countries in the European Union before the expansion on May 1st 2004.

FGD - Flue Gas Desulphurization

Gtce – Gigatons of Carbon Energy

IPCC – Intergovernmental Panel on Climate Change

Steam coal - coal used in combustion, in which heat is generated to produce steam, which is used to drive the turbines that produce electricity. Bituminous coal is often utilized for steam generation in electric power plants and industrial boiler plants (Energy Information Administration, 2007)

TEW – Tons of Evaporated Water

UNECE - United Nations Economic Commission for Europe

CHAPTER 1 Introduction

1.1 Preamble

The primary purpose of this report is to analyze the possibility of coal's contribution to environmentally sustainable resource development in Poland and identify the ways to enhance that contribution.

1.2 Problem Statement

The main task for the Polish energy sector, which is based mainly on coal, is to meet energy demand in an environmentally sustainable, affordable and secure way while making significant contribution to economic and social development.

Building sustainability on alternative energy sources is currently not possible, because Poland has limited primary energy sources, and little potential for renewable energy development. It is not clear if coal contributes to sustainable development. The main concern regarding coal and sustainability is associated with its environmental impacts.

The aim of this study is to assess whether coal use in Poland can contribute to sustainable energy development and examine the conditions in which coal extraction and use can be made more environmentally sustainable.

1.3 Context

The realization of the above is very important, because hard-coal, which is the major source of greenhouse gas emissions in Poland, will remain in the future the basis for electricity and heat generation in Poland.

Under the Guidelines for Poland's Energy Policy until 2025 (Ministry of Economy and Labor 2005) as well as according to World Energy Council (2004) forecast, coal will continue to be the most important fuel in terms of electricity production in Poland.

According to the World Energy Council (2004), the energy demand as well as electricity demand in Poland will increase in the next decades. The expected growth of demand for energy, and particularly for electricity, may cause a significant increase of power sector demand for coal. Increased coal production may generate more environmental problems (World Energy Council, 2004).

Issues related to environment protection were the basis of many international initiatives, conventions and agreements, which were signed and ratified by Poland. The most important are the UN Framework Convention on Climate Change (Rio de Janeiro 1992) and the Kyoto Protocol (1997). Furthermore, Poland's accession to the EU resulted in the significant increase in requirements concerning allowed emissions of SO₂, NO_x, and CO₂. To fulfill the objectives stated in these agreements and to map out Poland's route towards sustainable energy development, it is necessary to make appropriate technological and policy changes regarding coal production and coal utilization issues in Poland.

1.4 Objectives

The goal of this study was to analyze coal's contribution to sustainable resource development in Poland and identify ways which would help to increase that contribution. Specifically the objectives were:

1. To identify the main environmental impacts of coal as an energy source in Poland;

2. To describe existing Polish laws and related EU laws and regulations aimed at ensuring coal use is sustainable;
3. To establish target issues for making coal use more environmentally sustainable;
and
4. To examine how technological or other improvements can contribute to improving the environmental sustainability of target issues.

1.5 Background

Coal is the most abundant and commonly used energy resource in the world (International Energy Agency, 1997). Coal is classified into four categories. They include lignite, subbituminous, bituminous and anthracite (Montgomery, 2003). Among them anthracite, bituminous, and higher rank subbituminous have the most calorific value of more than 5.700 Kcal/kg on moisture, ash-free basis (World Bank, 2007). According to The American Society of Mechanical Engineers (ASME), they are classified in the hard-coal category.

The estimated world reserve of coal is about one trillion tons; total resources are estimated at over 10 trillion tons (Montgomery, 2003). Due to high transportation costs, coal is most often both produced and used in the region of origin. In coal-producing countries, coal is often the cheapest fuel for electricity and heat production. In 2000, coal supplied about 24% of global primary energy demand and was used to produce 38% of the world's electricity (Montgomery, 2003).

Poland (Figure 1) is the second biggest European producer of coal (Blaschke, 2004). Coal is Poland's primary natural resource and historically has been a major source of export revenue.



Figure 1 Location of Poland (Source: <http://www.worldcountries.info/Maps/Region/Europe-450-Poland.jpg>)

Coal sector was a help after World War II in rebuilding the Polish country (Nowak, 1991). In the post war period Polish hard-coal industry was treated as a driving force of the economy. During the centrally planned economy energy supply was built into the social system with the same priority as food supply. Energy has become more political than economic category (Nowak, 1991). Coal industry was very important to the communist regime. During communism Poland's economic policy was dependant on political and economic decisions made in former Soviet Union which had an important

influence on the coal industry in Poland. The Soviet model of development through heavy industrialization and military strength was introduced in Poland, resulting in rising demand for coal used by the metallurgical, engineering and electric power industries. Coal surplus to domestic needs in Poland had guaranteed market in the Soviet Union. Polish coal was seen by Soviet Union as an important contributor to Soviet economic performance (Riley and Tkocz, 1998). There was also an ideological aspect of the communist regime emphasis on the heavy industries. There was a belief that the “working class”, mainly the employees of the large state owned industries, was the driving force of the changes that would transform the whole socio-economic structure of Poland into the ideal communist system. Thus, the coal sector remained such an important industry, receiving strong economic and social support, even though there was no economic justification for those privileges (Europe Economics, 2006). In accordance with the economic policy coal was cheap and subsidized. The industry did not have to take into the account the cost of this fuel. It did not have to apply energy efficient, modern technologies. The industry’s task was to supply the needed quantities of coal, regardless the price (Olszowski, 2004).

With the changes of the industry structure in the post-communist era the role of the coal sector has become less important, however it still has a large influence on the economic and political life in Poland (Europe Economics, 2006). Changing attitudes about the value and reasonable prices for energy became one of the most difficult tasks in restructuring the sector and in initiating an appropriate energy policy changes (Nowak, 1991).

In 1989 the hard-coal mining sector in Poland entered into the process of transformation. All the coal mines were unprofitable and their main objective was to

produce as much coal as possible. Coal mines had high overemployment ratio, high costs of production, low coal prices and overcapacity. The main objective of the reforms was to achieve profitable production. The governmental subsidies for coal production were reduced at the beginning of 1992. Coal mines were established as independent enterprises, but when the industry was left without the subsidies, separate coal mines were economically too weak to survive, so they were merged into seven coal companies (Blaschke and Gawlik, 1999). As a result of the restructuring process, the number of mines as well as consumption of coal in Poland has been reduced. In 1990 coal consumption was 120 m tons gradually declining to 83 m tons in 2003 (Ministry of Economy, Labour and Social Policy, 2004).

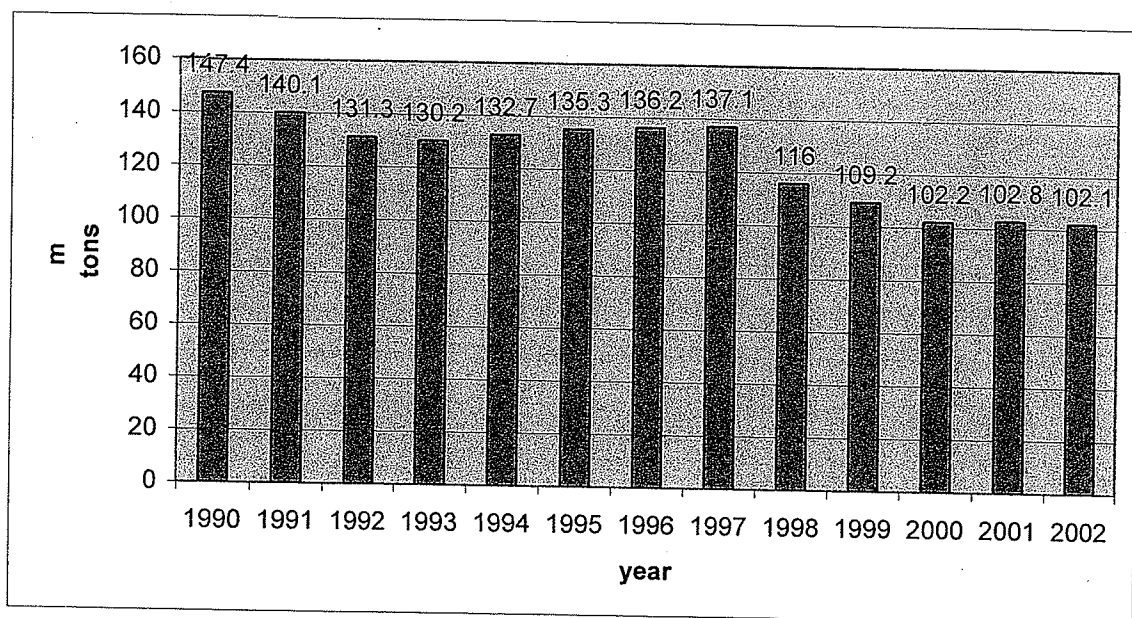


Figure 2 Hard-coal production in the years 1990 – 2002 in Poland (Source: Ministry of Economy, Labour and Social Policy 2004)

Hard-coal production decreased since the beginning of the nineties. In 1990 the coal production was 147.4 m tons and declined to 102.1 m tons in 2002 (Figure 2) (Ministry of Economy, Labour and Social Policy, 2004).

Utility power plants and CHPs account for the largest portion of total coal consumption in Poland (52%), the next are households, heat only boilers, industry and other sector of economy (27%), coking plants (15%) and industrial power generation (6%) (Ministry of Economy, Labour and Social Policy, 2004).

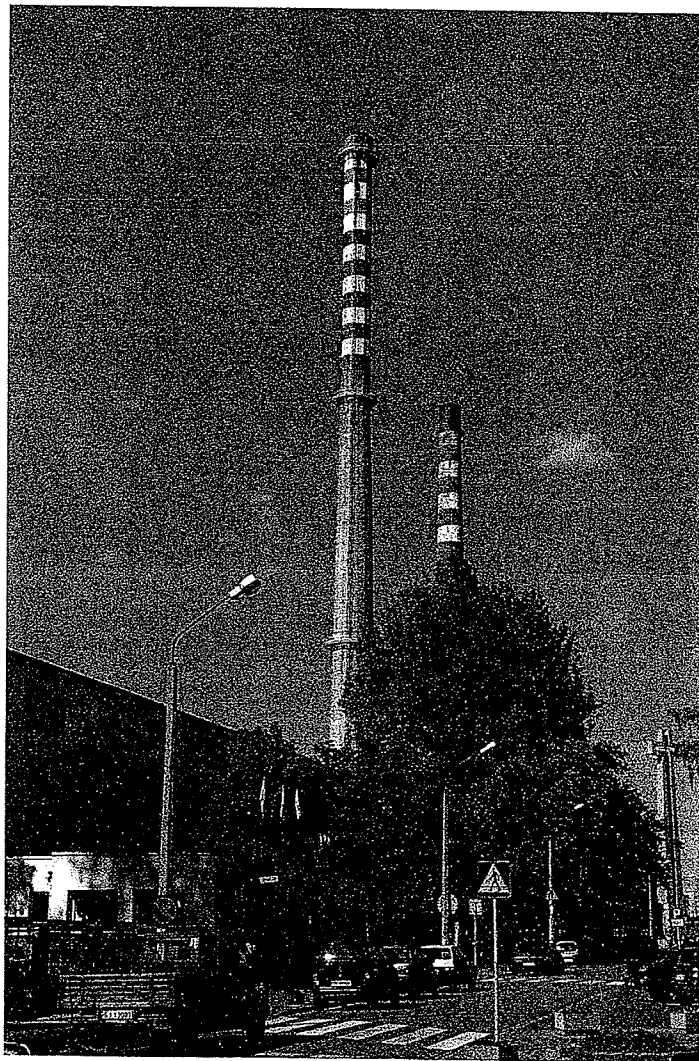


Plate 1 Power station “Pokoj” in Poland, June 2006

Coal generates 95% of power generation (Plate 1) and 77% of heat generation in Poland (Ministry of Economy, Labour and Social Policy, 2004).

The demand for hard-coal in 2004 was at about 78 – 80 m tons, including 66 m tons of steam coal (Plate 2) and about 13.5 m tons of coking coal. Twenty to 22 m tons were exported. In 2003 the hard-coal imports to Poland remained at the level of about 2.6 m tons. The forecast for steam coal import shows that it will remain at the level of 2.8 m tons (Ministry of Economy, Labour and Social Policy, 2004). Coking coal import is expected to be at the level of 0.3 m tons (Ministry of Economy, Labour and Social Policy, 2004).

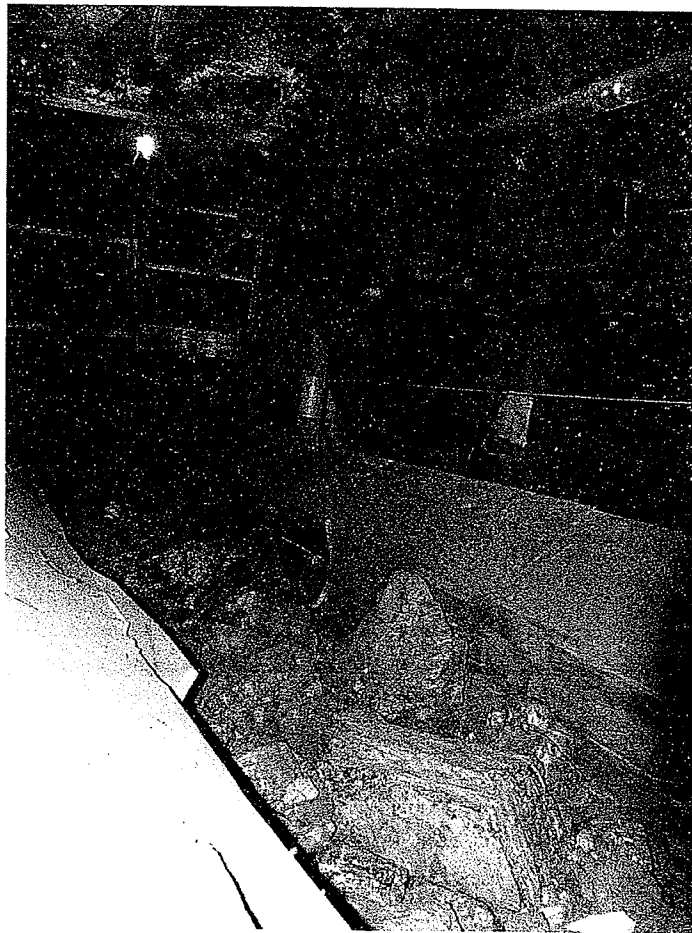


Plate 2 Steam coal from the coal mine “Szombierki”, Upper Silesia Coal Basin, April 2006

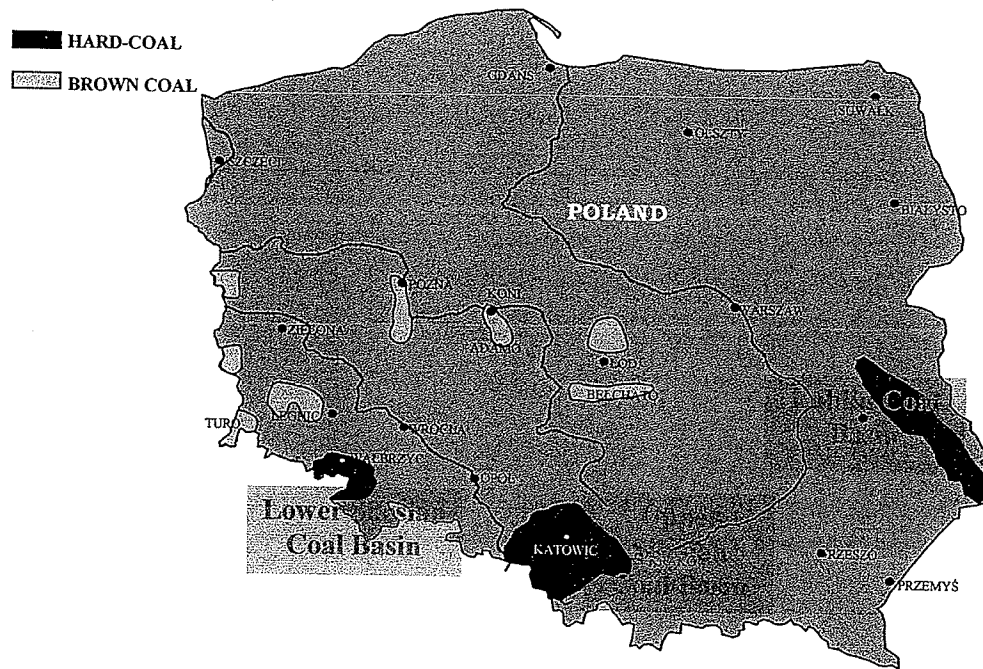


Figure 3 Coal Basins in Poland (Source: Agency for Industry Restructuring, Poland)

Polish hard-coal deposits are found in three coal basins (Figure 3).

First of them, Upper Silesia Coal Basin (Plate 3) contains 79.8% of documented viable hard-coal reserves. Mainly steam coal and anthracite can be found there. In 2002, hard-coal reserves in Upper Silesia Coal Basin were as follows:

- Viable geological reserves: 34. 826 m tons
- Industrial reserves: 7. 045 m tons
- Non-viable geological reserves: 22.095 m tons (Ministry of Economy, Labour, and Social Policy, 2004).

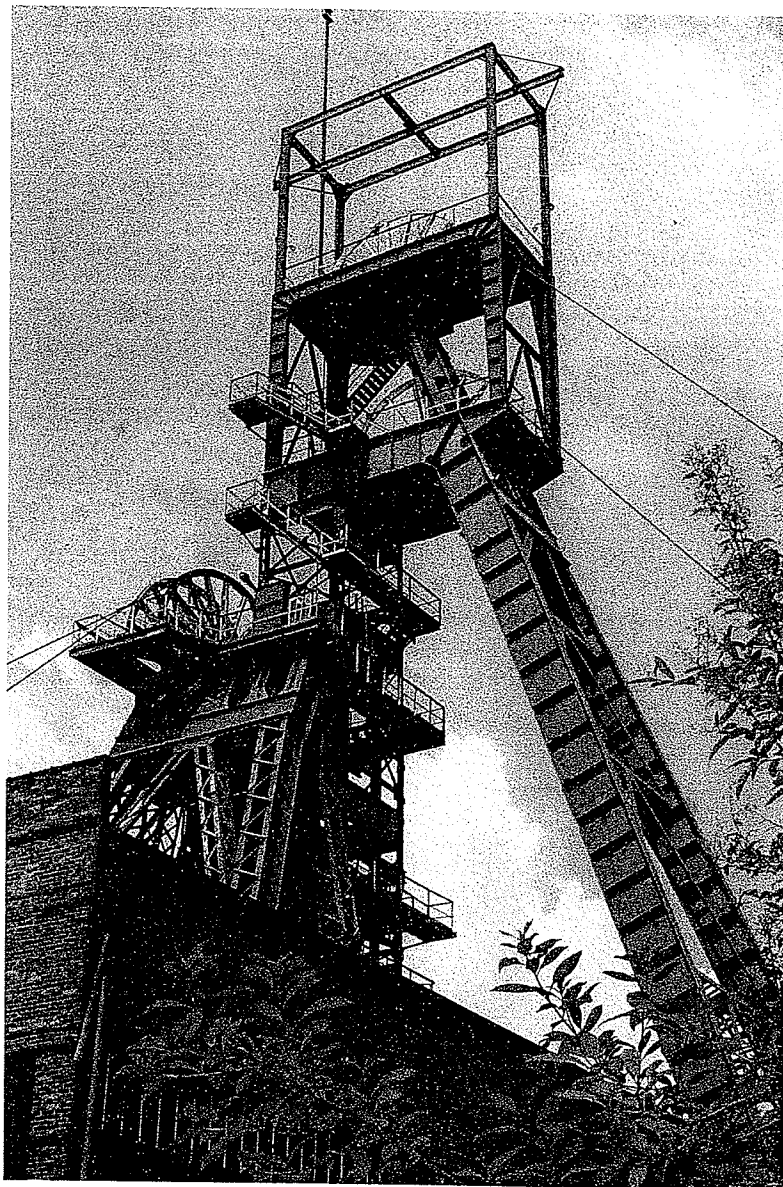


Plate 3 Lift shaft in Katowice - Upper Silesia Coal Basin, June 2006

In Lubelskie Coal Basin, second biggest coal basin in Poland, hard-coal with average ash content of 14.63%, and the total sulfur ranging between 1.21% and 1.46% can be found. In 2002, hard-coal reserves of Lubelskie Coal Basin were as follows:

- Viable geological reserves: 9. 259 m tons
- Industrial reserves: 334 m tons
- Non-viable geological reserves: 6. 918 m tons (Ministry of Economy, Labour, and Social Policy, 2004).

In 2000, mining operations in third coal basin, Lower Silesia Coal Basin, have been discontinued. Viable reserves in that area are estimated at the level of about 369 m tons, but in the mineral balance, these reserves are recognized as non-viable (Ministry of Economy, Labour and Social Policy, 2004).

In 2002, the amount of operational reserves in Poland was estimated at 5.0 billion tons, with over 50% easily accessible reserves (Ministry of Economy, Labour and Social Policy, 2004). The main operational reserves are the steam coal reserves (Ministry of Economy, Labour and Social Policy, 2004).

During the transformation period employment in the industry has dropped from 415 900 persons in 1989 to 140 700 in 2002 (Figure 4) (Ministry of Economy, Labour and Social Policy, 2004). As of December 31st 2003, mining companies employed 136 454 persons; 105 127 persons worked underground (77%) (Plate 4), and on the surface 31 327 persons (23%) (Ministry of Economy, Labour and Social Policy, 2004).

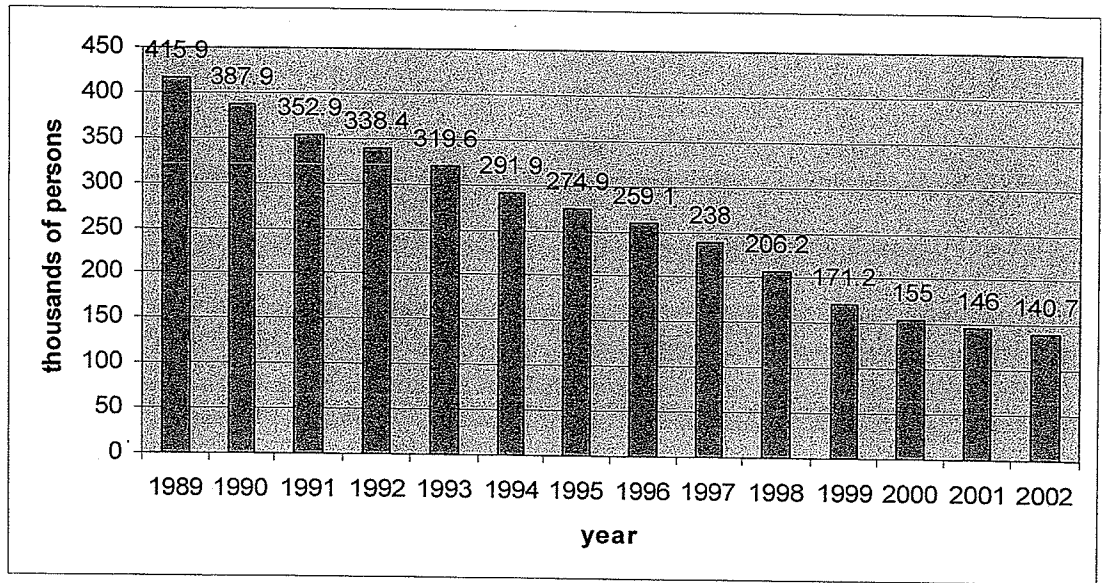


Figure 4 Employment in hard-coal industry in 1989-2002 (Source: Ministry of Economy, Labour and Social Policy 2004)



Plate 4 Coal miners working underground in the coal mine "Szombierki", Upper Silesia Coal Basin, April 2006

The processes of transformation directly influenced the Silesia region, an area of coal exploitation, on at least three dimensions: its economy, environment, and society. One of the most painful was the impact on the society. The transformation of that area has been accompanied by several forms of deep changes experienced by the families of miners. Traditionally, miners were financially privileged, with an average income double the national average (Szczepanski, 1996). In 1995 that proportion dropped substantially causing their economic degradation (Szczepanski, 1996). A second type of degradation experienced by coal workers is prestige degradation. In the period of real socialism, manipulative communist philosophy tried to convince working class in heavy industry that they had a special mission in the development of civilization. The idea of miner profession as a special profession has changed in the transformation process, but no explanations about the transformations resulted in deep feelings of discrimination among coal miners (Szczepanski, 1996).

While social impact of the transformation is very significant in the Silesia region, one of the most important problems of the coal industry in Poland, however, remains its negative influence on the environment. Still there is the predominance of coal in Poland's energy production and consumption mix which results in large amounts of carbon emissions and environmental pollution (Plate 5). The Polish government signed and ratified several international commitments regarding the reduction of the emissions.

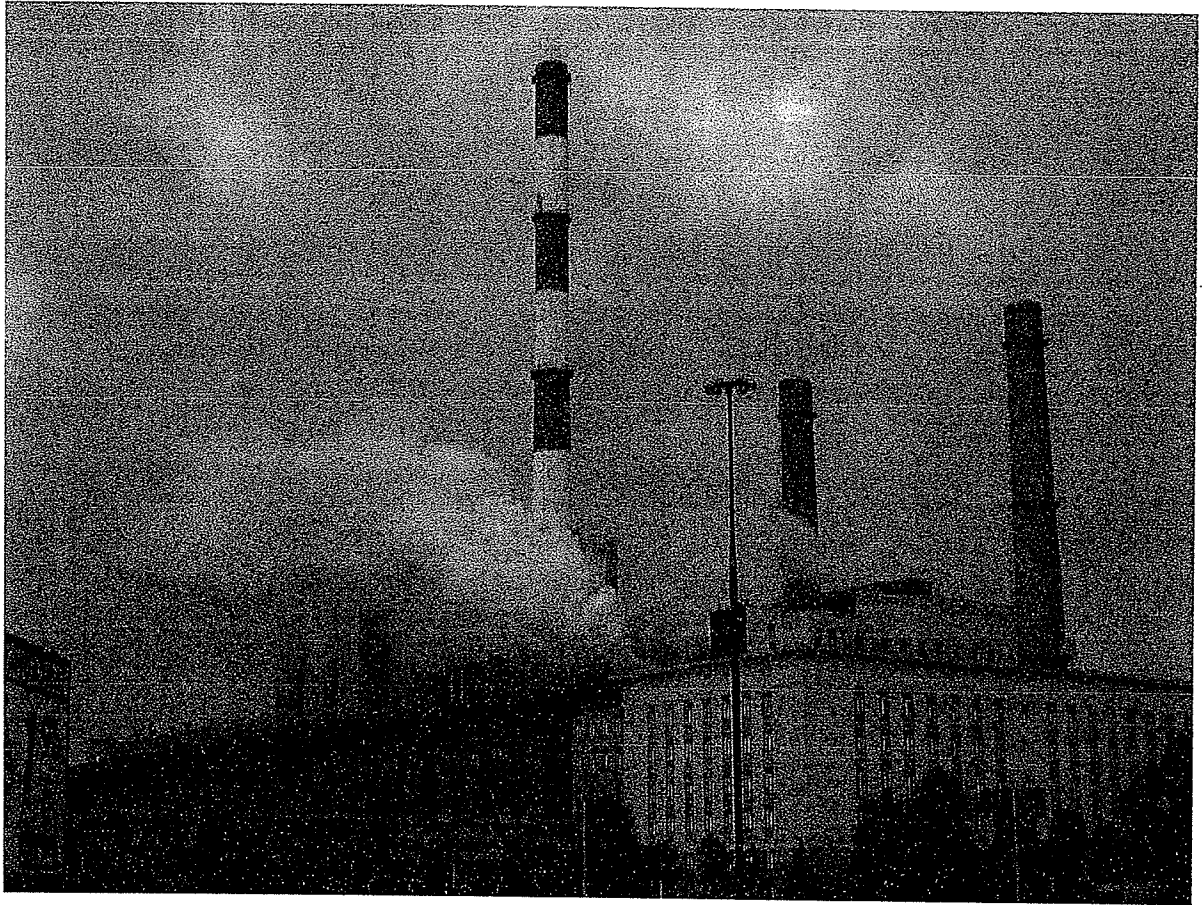


Plate 5 Power station “Zeran” emitting pollution, Warsaw, December 2007

Poland has agreed to reduce greenhouse gases 6% below its 1988 levels by the 2008-2012 under the Kyoto Protocol, which the Polish government signed on July 15th, 1998 and ratified in August 2002 (Energy Information Administration, 2003).

The country is also a signatory of other agreements on the control of emissions that include the UNECE Long Range Transboundary Air Pollution Convention and the UNECE Second Sulfur and NO_x Protocols (International Energy Agency, 2004). Reductions agreed under the Second Sulphur Protocol are a 37% reduction by 2000 on a 1980 baseline, 47% reduction by 2005 and 66% by 2010 (International Energy Agency, 2004). Nationally, legislative progress has been made through the adoption of framework laws in 2001 that include the 2nd National Environmental Policy that incorporates the

principles of the EU 5th and 6th Environmental Action Programs: climate change, nature and biodiversity, environment and health, and natural resources and waste (International Energy Agency, 2004).

Poland has also obligations resulting from strict emissions standards included in several European Union Directives. In advance of joining the EU in 2004, Poland negotiated an extension in implementing the EU IPPC Directives, obligating EU members to reduce levels of emissions, until 2010. This extension gives Polish power plants time to adapt to meet stricter emissions levels for SO₂, NO_x and particulates (International Energy Agency, 2004). Poland also received an extension on implementation of EU air pollution regulations covering large combustion plant until 2017 (International Energy Agency, 2004).

Poland has already made efforts to reduce the environmental impact of energy production and since 1990s, all new power plants have been equipped with new installations, including low NO_x concentric firing systems, swirl low NO_x burners, flue gas recirculation, and limestone/gypsum flue gas desulphurization (FGD) systems. These measures, plus the increased use of lower sulfur coals, have resulted in significant environmental improvements.

As a result, since 1989, energy-related carbon emissions in Poland have decreased to 78.6 million metric tons of carbon, compared to an average of approximately 110 million metric tons emitted annually during the 1980s. (Energy Information Administration, 2003)

By 2010, it is estimated that Polish CO₂ emissions will decrease at a rate around 30% lower than the country's baseline year of 1988. However, the emission level is still one of the highest in Europe (Energy Information Administration, 2003).

While emissions are the main environmental impacts resulting from coal production and consumption, there are other impacts such as saline waters, mine wastes, and ground settling.

1.6 Limitations

The study focused only on hard-coal as a source of energy and did not discuss other kinds of coal, which have much lower contribution in overall energy use in Poland.

The research time frame of the historical data started in 1990, when the process of transformation of the Polish hard-coal industry began. The report does not discuss in details earlier events in the Polish coal sector.

Because of the limited resources, the survey conducted during the research was carried only with selected coal industry representatives, coal communities and associations, Polish government, financial institutions, and academia. It did not cover the engineering and equipment supply industries, the electric power utilities, and the non-power industrial users of coal, such as the steel and chemicals industries.

1.7 Organization of the Study

The research thesis is organized in six main chapters. The first chapter provides an overview of the background, problem statement / purpose, objectives, context, overview of research methods and delimitations of the study.

The second chapter is more specific in its focus on preparing the conceptual and theoretical base of the research. It provides a critical literature review and discusses the main body of the literature from which the research would draw upon and may make contributions to.

The third chapter outlines research methods including the process of conducting the research in the field, data collection and interpretation, and report writing.

Chapters four, five and six discuss the results of the study conducted and give the recommendations.

CHAPTER 2 Hard-Coal Industry in Perspective

2.1 Restructuring of the Polish Hard-Coal Industry

2.1.1 Overview of Restructuring of the European Hard-Coal Industry

Restructuring of the European hard-coal industry began at the end of the 1950-ties and is still in progress. The European coal-industry has been declining continuously both in terms of production and the workforce (Rabanal, 2003). The process of restructuring of hard-coal industries was different in different countries. Belgium, Holland, Portugal and France completely closed their hard-coal industries. Germany, Spain and the United Kingdom have been gradually limiting production of coal and have been reducing the employment, trying, at the same time, to modernize and rationalize the industry (Olszowski, 2004). In those countries coal production was brought to a condition of a profitable activity because of public aid. The success of the restructuring process of hard-coal industries in the member countries of the first fifteen EU countries was related to financial support received from the European Union. The main objective of that aid was to minimize the social and regional costs of restructuring and the decrease of coal production and to promote, at the same time, options for developing other economic activities (Rabanal, 2003). It covered half of the costs of realization of the restructuring processes. Between 1951 and 2002 the restructuring processes were also financed by the European Coal and Steel Community, the European Social Fund, the European Regional Development Fund, and also by the European Development Bank (Olszowski, 2004).

After expiry of the European Coal and Steel Community Treaty in 2002, the guidelines for hard-coal industry's reforms have been modified and nowadays funds for coal restructuring come from the state budgets of member countries. These new rules are unfair for the new members of the European Union, such as Poland, where the

restructuring process of hard-coal sector is being implemented under very difficult conditions resulting from transformation of the whole economic and political systems (Olszowski, 2004)

2.1.2 Polish Hard-Coal Industry in the Times of the Socialist Economy

In the post World War II period the Polish hard-coal industry was treated as a driving force of the economy. Coal at that time was cheap and subsidized. The manufacturing industry did not have to take into the account the cost of this fuel and did not have to economize. It was not required to apply energy efficient, modern technologies. The hard-coal industry's task was to supply the needed quantities of coal, regardless of price (Olszowski, 2004). The sales of coal were performed by state central organizations. The financial resources for financing of unprofitable production came from profitable coal exports (Nowak, 1991). Among the priority tasks of mining industry, besides productions, was maintaining living base for the employees. The hard-coal industry was forced, to build and then maintain housing estates, roads, hospitals, recreational centers, sports and cultural facilities, together with the whole associated infrastructure. In 1989, at the beginning of economic system's changes, Polish hard-coal industry was the owner of enormous, unproductive assets. The industry produced 177.4 m tons of coal and employed 415 700 persons in 70 mines. (Olszowski, 2004).

2.1.3 Restructuring of Polish Hard-Coal Sector in 1990-1997

From 1990-1997 hard-coal industry was reformed on the basis of six restructuring programs. The main objectives of each of those programs emphasized the need of bringing profitability to the hard-coal industry but, after seven years of those reforms the objective failed to be achieved. According to Olszowski (2004), mentioned above

programs did not reflect the solutions applied in the countries of EU-15. At the end of 1997 hard-coal industry production capacity was reduced to the level of 137.1 m ton (Olszowski, 2004). Since 1990, a significant decrease of domestic demand for coal has taken place. Coal sales in 1997 were much lower than in 1990 (Blaschke and Gawlik, 1999). The situation occurred, because coal was not as cheap as it used to be and also because the high value of the Polish zloty against foreign currencies encouraged the import of other, less-polluting sources of energy, like natural gas and oil (Blaschke and Gawlik, 1999).

2.1.4 Reforms of Polish Hard-Coal Sector in 1998-2003

From 1998-2003 two government programs of hard-coal industry's restructuring were implemented. Those were complex documents, covering the wide range of issues associated with both with technical, financial and employment restructuring as well as with the regional aspect of the reforms, including improvement of management strategies development, privatization, investments and also environment protection. The sources and rules of the reforms' financing were outlined in the programs (Olszowski, 2004).

During this period the production capacity of hard-coal decreased at Polish mines by 36.7 m ton (Ministry of Economy, Labour and Social Policy, 2004). In 2000, for the first time since six years, the hard-coal industry had a positive financial result on coal sales (Olszowski, 2004). In 2001, for the first time since 11 years, the sector achieved a positive net financial result. In the last year of the considered period the hard-coal industry employed 136 400 persons, and the production was 100.4 m ton (Olszowski, 2004).

2.1.5 Actual Program for Restructuring of Hard-Coal Mining in Poland

On 28 January 2003 the Council of Ministers adopted The Program For Restructuring of Hard-coal Mining in Poland From 2003 To 2006, taking account of the anti-crisis laws and initiating the privatisation of certain mines. The restructuring processes currently underway in the sector are based on the document The Restructuring of Hard-coal Mining From 2004 To 2006 And The Strategy For The Years 2007 – 2010 adopted by the Council of Ministers on 27 April 2004. The legal basis for the implementation of this program is the act of 28 November 2003 The Restructuring of Hard-coal Mining From 2003 To 2006.

In September 2006 Ministry of Economy presented a draft of new document The Strategy for Hard-coal Industry Activity In The Years 2007-2015. The document was adopted by the Council of Ministers on 31 July 2007. The document does not describe detailed restructuring methods but sets directions regarding the strategy of mining industry activities.

2.1.6 Conclusions on the Polish Hard-Coal Industry Restructuring Process

In 1990-2003 Poland thoroughly restructured the hard-coal industry. Nowadays the most important targets for the Polish hard-coal industry are to improve production effectiveness and to invest in technological progress. Therefore, creation of the best possible conditions for investments and financial support for the hard-coal industry should be among the priorities.

Poland has a restructured, modern coal mining industry which is able to produce coal at comparatively low costs. The coal sector possesses very good base consisting of Polish scientific-research centers, manufactures of mining machines and equipment and

also hundreds of companies specialized in services for coal industry. Polish reserves of hard-coal are still the largest in Europe (Olszowski, 2004).

It seems very rational to utilize such potential to increase the energy security of the European Union in the days of its great dependence on external supplies of energy sources. However, it is necessary to remember that over the time, coal being the primary energy source has also caused problems, particularly to the environment. Taking the advantage of this widely distributed energy source and building it into sustainable energy policy, the condition of improving its environmental performance has to be fulfilled.

2.1.7 Energy Policy of Poland until 2025

The importance of protecting the environment from the negative effects of energy-related activities, concerning generation, transmission, and distribution of energy and fuels is emphasised in the document Energy Policy of Poland until 2025. Besides the environment protection the main objectives of the Polish energy policy include: ensuring energy security of the country and increasing the competitiveness of the economy and its energy efficiency (Energy Policy of Poland until 2025, 2005).

The Policy defines the basic concept of the energy sector, which are the following:

- energy security, which is the state of economy which allows to meet current and future demand on fuels and energy in technically and economically reasonable way, while ensuring minimization of negative effect of the energy sector on environment and public life conditions, and
- ecological security, which is defined as “the condition in which the pressure of all sectors of the economy, including the energy sector, upon the

environment is being decreased. This allows to maintain, at least on the current level, the diversity of biological forms of life, allows for the effective protection of health and lives of people, and for the preservation of nature and landscape, as well as ensures effective fulfilment of Poland's international commitments in the field of environmental protection" (Energy Policy of Poland until 2025 page 5, 2005).

According to Energy Policy of Poland until 2025, to achieve ecological security, several actions should be undertaken within the energy management area. They include:

- limiting environmentally negative effects of fuels utilization;
- improving energy efficiency of energy carriers processing, transmission and use;
- limiting emissions of pollutants to environment; and
- promoting renewable energy sources.

The governmental document has introduced the ideas of ecological security and defined the following actions which are necessary for pro-ecological energy policy:

- Complete adaptation of installations which burn out primary energy sources to statutory requirements on environmental control. Accession Treaty obligates Poland to meet more strict limits for emissions (as specified in Directives 2001/80/EC and 2001/81/EC about SO₂ and NO_x); furthermore, the Kyoto Protocol, which requires reduction of CO₂ emission, is also binding.
- Introduction of Clean Coal Technologies would ensure coal domination while meeting the environmental standards. Actions would be also taken aiming at CO₂ capturing and sequestration.

- Minimization of coal-mining impact on the environment would be made by reduction of salty mine-water discharges, use of mining techniques which minimize mining damages, higher waste utilization levels, and post-mining reclamation.
- Introduction of mechanisms that reduce emissions of pollutants to atmosphere by emission trading system (Energy Policy of Poland until 2025, 2005).

As described above “Energy Policy of Poland until 2025” is one of the documents which aim at creating the basis of sustainable energy policy framework in Poland.

2.2 Coal and Sustainable Energy Policy

The term “sustainability” entered into common use after the publication of the report “Our Common Future” by the United Nations’ Brundtland Commission in 1987. The commission defined sustainability, and in particular sustainable development, as “development that meets the needs of the present without compromising the ability of future generations to meet their needs.” (United Nations, 1987).

Klaus Brendow (2004) states that sustainable energy development can be assessed against three key issues:

- the continued availability of energy, in sufficient quality and amount, adapted to the changing customer needs;
- the rising accessibility of energy;
- the acceptability of energy (Brendow, 2004).

The sustainable energy policy is relatively new in the EU and completely new in Poland. Since it contributes to the whole concept of sustainable development, it now defines priority in creating energy policies within Poland and EU (Skoczkowski, 2003).

According to Skoczkowski (2003), appropriately created sustainable energy system should provide secure energy supplies, be competitive and efficient, should contribute to economic development, help to create employment, protect the environment, and maintain the ecological sustainability.

According to Coal Industry Advisory Board (2003), coal can play a significant role in energy systems that support sustainable development. It is affordable, safe to transport and store, and widely distributed, hence coal remains an important source in maintaining a diverse, balanced and secure energy system. It can also meet the growing energy needs and contribute to economic and social development (Coal Industry Advisory Board, 2003). Coal however, has still under current conditions poor environmental performance; therefore its contribution to environmentally sustainable development is questionable. In the Polish case it reasonable to consider how this resource should be managed and how it can contribute to the creation of a clean and sustainable future, because this country has relatively high coal supplies.

According to Skoczkowski (2003), the main task in creating sustainable energy policy is to identify all current and long-term challenges and to develop strategies to respond to meet these challenges. Therefore, when considering incorporating coal into sustainable energy system, it is necessary to examine the main environmental concerns of coal use and areas for improvement within coal utilization process. According to Nagy *et al.* (2006), the greenhouse gas emissions resulting in climate change are the main impact on the environment associated with coal use, which will be discussed later in the report. Concerns about climate change are the most complex challenge to the long-term use of coal in a sustainable development context. Clean coal technology deployment may be the

solution for meeting by coal strict environmental standards. According to Coal Industry Advisory Board (2003), improvement in coal environmental performance is technologically feasible and enhancing coal's contribution to environmental sustainability should be a priority for industry and governments.

In evaluating resource use the questions have to be asked how to measure its sustainability. According to Moffatt *et al.* (2001), evaluating sustainable development there is a need to develop indicators based on data. It is very important to use reliable data to accurately reflect the condition of the environment. It is very useful to examine local, national and global indicators of sustainable development to discover which variables are common to all of them. In considering environmental sustainability of resource use Moffatt *et al.* (2001) propose to evaluate the emissions of greenhouse gases which are causing the global climate change. By showing that the energy resource (in Polish case - coal) effectively protects the environment through minimizing greenhouse gas emissions to the target levels, it would be possible to ensure that this energy carrier can contribute to environmentally sustainable energy systems.

2.3 The legal Framework for the Implementation of Climate Policy in Poland

As mentioned earlier, climate change is the main environmental challenge in creating the strategies for sustainable resource development. This challenge was also recognized by the United Nations Organization, which adopted at the Earth Summit in Rio de Janeiro in 1992 the United Nations Framework Convention on Climate Change, which was then signed by more than 150 countries, including Poland (Ministry of Environment, 2006). The Convention came into effect in March 1994. Poland has been a party to the Convention since 1994, which means the responsibility to take action to

minimize greenhouse gas emissions in the atmosphere at levels preventing global climate change (Ministry of Environment, 2003).

The strategic documents, discussed below are important for climate protection actions in Poland.

The Second National Environmental Policy sets out the directions of measures to reduce the energy intensity of the economy. The National Environmental Policy for 2003-2006 Considering the Outlook for 2007-2010 refers to the priority directions of action laid down in the adopted Environment Action Program of the European Union (Ministry of Environment, 2003). According to the National Environmental Policy, the environmental concerns should be integrated into the sectoral policies in the all fields of the economy and into the development strategies and programs at regional and local levels.

Poland 2025 – A Long-term Strategy for Sustained and Sustainable Development specifies the provision of Article 5 of the Constitution of the Republic of Poland (Ministry of Environment, 2003). One of the objectives of the Strategy is the need for the elimination of economic activities harmful for the environment and human health, as well as the promotion of environmentally sustainable ways of management. Climate change issues related to greenhouse gas emission reductions are addressed in this document. This document emphasizes the need for reducing the energy intensity to fulfill Poland's commitments under the Kyoto Protocol (Ministry of Economy, 2003).

In the document Energy Policy of Poland until 2025, the most important objectives are defined as the care of the energy security of the country, the need for

competitiveness improvements in the energy sector as well as the care of the protection of the natural environment by minimization of the negative impact of the energy sector.

2.4 Technological Status of Energy Sector in Poland

Poland's energy sector is currently dominated by coal-fired power plants. Poland's power generation system is outdated, with more than 30% of the nation's power generation equipment over thirty years old (The Business of the Environment, 2006).

However, in the 1990s, some improvements were made in order to minimize greenhouse gas emissions. To control NO_x emissions from power plants the use of overfire air, low NO_x concentric firing systems, swirl low NO_x burners, flue gas recirculation, and low temperature vortex combustion were started. SO₂ emissions are controlled by the use of limestone/gypsum flue gas desulphurization (FGD) systems. Some smaller facilities use dry or semi-dry FGD-based technologies (Stanczyk *et al.*, 2001).

CHAPTER 3 Research Methods

3.1 Introduction

The research focused on the collection of both historical and current data so that a comprehensive analysis of industry restructuring in Poland could be conducted, to understand the extent, mechanisms and impacts of this process.

The research time frame of the historical data started in 1990, when the process of restructuring of Polish hard-coal industry began. The year 1990 was also associated with the time of transformation in Poland, which resulted in releasing the data regarding the actual mining indicators and greenhouse gas emissions levels. The data before 1990 during the years of communism and centrally planned economy were not available.

As mentioned before, during the study only the future role of hard-coal as a source of energy in Poland was analyzed. The term hard-coal was defined by The American Society of Mechanical Engineers as coal with a gross calorific value of more than 5.700 Kcal/kg on moisture, ash-free basis. The hard-coal category includes anthracite, bituminous, and higher rank subbituminous.

The research objectives were achieved using the following methods: review of secondary data sources, attending meetings and conferences, open-ended interviews with coal experts, and field work observation.

3.1.1 Review of Secondary Data Sources

The research started with an extensive literature review. It included review of the books related to comprehensive perspective of energy policy, economics and the environment, Polish and EU laws and regulations, journals, internet, government and specialist reports.

Among all secondary data sources the most important, relevant and useful were government sources. They provided researcher with up to date information related to hard-coal sector in Poland.

Review of secondary data sources was an effective tool for finding background information regarding the main environmental impacts of coal as an energy source in Poland.

By examining Polish and UE laws and regulations using data base of law documents, I was able to describe existing Polish laws and related EU laws and regulations aimed at ensuring coal use is sustainable.

Review of the secondary data sources was also one of the methods used to examine the extent to which technological or other improvements can contribute to improving the environmental sustainability of coal use in Poland.

3.1.2 Meetings and Conferences

It was important to do field research and attend the specialist meetings and conferences to perform accurate analysis of current situation in coal industry regarding applied technologies and problems related to negative influence of coal mining on the environment in Poland.

Attending the latest conferences (in 2005 and 2006) was useful in terms of:

- gaining knowledge regarding innovative and evolving technologies in the coal industry,
- dealing with technical solutions to problems, specific strategies, and projects in coal industry, innovations, industry trends, and regulatory compliance.
- exchanging information on power generation and policy issues.

One of the most useful conferences attended was “The Clearwater International Technical Conference on Coal Utilization & Fuel Systems” held on April 17-21, 2005 in Clearwater, Florida, USA.

The conference was organized by: U.S. Department of Energy, Coal Technology Association & American Society of Mechanical Engineers - Fuels & Combustion Technologies Division, in cooperation with the National Energy Technology Laboratory, U.S. Department of Energy. The conference covered innovative and evolving technologies in coal industry and allowed me to exchange information on power generation and policy issues.

Attending the conference gave me the opportunity to contact the following people regarding my research topic:

- R.A. (Bob) Stubbs, P. Eng. – Executive Director of Canadian Clean Power Coalition, Regina, SK, Canada
- Logan Zhen, Ph.D. – Research Scientist, Advanced Combustion Technologies, CANMET Energy Technology Centre, Natural Resources Canada, Nepean, Ontario, Canada.

I had very interesting conversations with both of the experts mentioned above, regarding the possibilities of clean coal technologies development, especially IGCC technology. The talk with Bob Stobbs was especially valuable, because he is directly involved in Phase I of the Canadian Clean Power Coalition Project which has been carried out over the past four years to evaluate technologies for coal-fired power generation that reduce all emissions, including CO₂. Technologies evaluated in that project included IGCC, oxyfuel combustion and amine scrubbing. The conclusion was

made that the most prospective technology for Poland would be the IGCC, however further research is needed in order to evaluate the feasibility of the future projects.

Being in Poland from March to June 2006 I took a part in a few meetings at the Ministry of the Economy. One of the most useful meetings took place on March 8, 2006. The meeting covered the issues related to current status of clean coal technologies in Poland and their perspectives for the future.

As a part of my field work I also attended the Conference "Future EU Energy Mix - will coal play an important role?" in Gliwice, Poland on 29 May 2006. The conference was organized by Silesian University of Technology. The most interesting talk in terms of my research project was the talk "A place for coal in the EU Energy Mix" and was presented by Andris Piebalgs - Energy Commissioner at the EU.

The conferences gave me the opportunity to enhance my knowledge regarding clean coal and getting current data on the status of clean coal technologies development and possibilities of introducing them in Poland. I talked to several people during the conferences and during the follow up talks discussing how technological or other improvements can contribute to improving the environmental sustainability of coal use in Poland. I included the data gathered during the conferences in the background section of the thesis as well as to support my findings in the results section. Also the survey participants were identified during talks and discussion taking place at the meetings and conferences.

3.1.3 Open-ended Interviews

It was necessary to interview key Polish experts in the fields of mining, engineering, environmental protection and also economy in order to establish target

issues for making coal use more environmentally sustainable and to develop the long - term strategies and actions, which could be undertaken by public authorities and other involved parties to evolve the role of coal into a sustainable energy system in Poland.

This required the researcher to spend a period of four months in Poland (March-June 2006), collecting and verifying the necessary data.

In the survey, open-ended questions were used to allow participants to formulate their own responses regarding coal in a sustainable perspective. According to Patton (1990), open-ended interviews are the most efficient techniques among qualitative interviews and are useful for reducing bias when several respondents are involved and when it is important to be able to compare the answers of different respondents.

The survey was carried out with multidisciplinary group of people (23) consisting of specialists from government and coal industry companies, coal communities and associations as well as academicians (Figure 5).

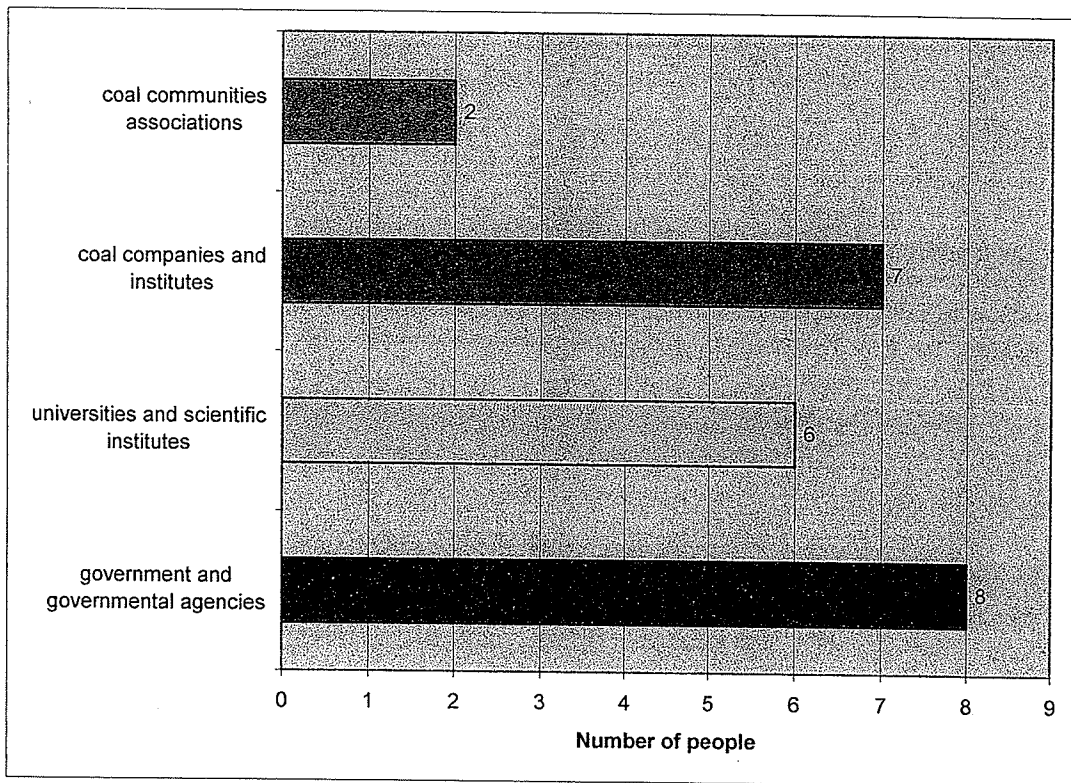


Figure 5 The number of people interviewed in each category

The respondents were identified during talks and discussions taking place at the meetings and conferences and were chosen to identify the spectrum of problems and possible solutions for the coal industry in Poland. The coal experts represented groups of people who play different roles in the coal industry. Some (government and coal industry companies) are the units responsible for changes and directions in coal industry, some have consultative role (academicians) and some are affected by the changes in coal mining sector in Poland. Choosing the respondents I wanted to look at the scheme of possible changes in mining sector, by identifying the “starting point” - the changes’ initiator, through scientists who can give their recommendations regarding the way of implementing those changes, and ending with people whose output would give the idea

on the consequences of the changes for the coal communities and be the voice of coal communities, representing public regarding possible shift in mining industry.

Choosing people differently affected by coal industry allowed me to avoid receiving biased information only from people being inside the industry for whom developing the sector is the main target and coal remains the main source of revenue.

I classified the respondents as the experts “from the industry” and “outside of the industry”. I interviewed 13 people from the first category and 10 from “outside of industry”. The institutions from which the experts were chosen are listed in Table 1.

Table 1 Institutions chosen for the survey

WITHIN COAL INDUSTRY	OUTSIDE OF COAL INDUSTRY
Central Mining Institute	Association of Mining Communities
Coal Companies	Krakow Silesian University of Technology
Industrial Development Agency	Ministry of Environment
Institute for Chemical Processing of Coal	Polish Academy of Science
Mining Chamber of Industry and Commerce	Silesian Union of Municipalities and Districts
Ministry of Economy	The National Fund for Environmental Protection
	University of Science and Technology

I also considered respondents background and experience as well as the role played in the coal mining industry. I interviewed people from the current government as well as people who were the members of the government a few years ago. They gave me the perspective on the obstacles to changing the coal mining sector. The interviews were scheduled mainly in the Silesia region, because most of the respondents have their offices in that area. As mentioned earlier, Silesia region is the place where mining industry in Poland is located.

During the survey the participants identified themselves by their individual names. The self-identification by the participants was part of the Polish culture where it is routine to introduce oneself to the outsiders by name and designation. The researcher protected the names of the participants by measure of anonymity. The researcher used the names of the participants in order to clarify or verify data and findings in the subsequent stages of the research. The names of the participants were recorded in a separate paper as differentiated from the data collection sheet in order to accord anonymity. At the same time, all data and names of participants remained under the strict supervision of the researcher and stored in a secured location, such as all the papers relating to the research were kept under lock and key and all the computer copies of the files were stored in the personal computer of the researcher with password protection. The research output presented collective information and there was no reference to individual participants in order to protect anonymity. After completing the research all records containing the participants' names were blacked out. The same measure was also taken in case of digital records by deleting the participants' names from such records after the research was finished. As the researcher is originally from Poland where the research was conducted, no translator was used for the research which gave the researcher the best opportunity to maintain confidentiality during the proposed research.

All the participants involved in the survey were working adults above the age of 18. During the survey the participants were asked a series of questions that helped the researcher to assess if coal use in Poland can make contribution to sustainable energy development and what are the ways to make coal use in Poland more environmentally sustainable. The survey session was usually from 45 minutes to 1.5 hour long. In some cases more time was required and a subsequent meeting was arranged. This survey was

conducted at participants' place of work. The researcher obtained permission from the experts through a letter written in Polish language. A copy of the letter in English has been attached as an Appendix 4 with this report. The letter was read to the participants in Polish language by the researcher at the beginning of the first meeting between the researcher and the coal experts. The participants were asked to confirm by signing the letter that they understand the purpose and content of the letter and agree to participate.

It is important to mention that all respondents were very interested in participating in the survey, especially those from universities and scientific institutes. Coal mining communities and associations were also involved in my project willing to give their input. My respondents saw clean coal technologies as the answer to more environmentally acceptable coal industry in Poland and for the continuation of the Silesia region development based on this commonly used energy source.

The project received a lot of interest among different groups of people, because the time when I started my field work was also the moment when the clean coal technologies issues started to be discussed in Poland and in European Union. It allowed me to be in Poland during the most important meetings and discussions.

During the field work, besides survey with coal experts, I had many other interesting informal interviews and talks which were considered in the report. They allowed me to clarify some issues and were the way of verifying data.

The questions of the survey as well as summarized experts' responses are presented in the Appendices 1 and 2.

The survey was used as a tool necessary for achieving all four research objectives:

- 1) identifying the main environmental impacts of coal as an energy source in Poland,

2) describing existing Polish laws and related EU laws and regulations aimed at ensuring coal use is sustainable, 3) establishing target issues for making coal use more environmentally sustainable, 4) examining how technological or other improvements can contribute to improving the environmental sustainability of target issues.

3.1.4 Field Observation

Participant observation allows the researcher to gain an intuitive understanding of a situation, which in turn allows a person to speak with confidence about the meaning of the data. It helps one to understand the meaning of one's observations (Bernard, 1988).

Field observation gave me the chance to draw a detailed picture of the coal restructuring processes going on in Poland as well as interactions within the coal industry itself. I recorded my observations in the field journal. My notes included a detailed description of the situations I became involved in and the places I visited. In the field journal I recorded information regarding conversations with coal experts and other interviewers and the schedule of events.

During my field work in Poland I had the opportunity to visit three coal mines (Plate 6). It allowed me to get an understanding of the importance to reduce the impact on the environment of the actually operated as well as already closed coal mines.

The field observation helped me to visualize some of the main negative effects of the coal mining activities on the environment, which were identified in the survey with coal experts.



Plate 6 Field observation - Upper Silesia, Poland, June 2006

3.2 Survey Bias

While a combination of methods allowed me to use data from different sources and helped to minimize the probability of obtaining biased information, concern regarding reliability was identified in the field. Survey with coal experts, closely related to the sector and having clear aim in increasing the role of coal in Poland, may have impact on the reliability of the open-ended interviews. To ensure that the perspectives

were well-rounded, the respondents from “outside of industry”, including community and academia representatives were interviewed.

3.3 Data Analysis

Most of the data collected throughout the research process were qualitative; however I also gathered and analyzed quantitative data.

One of the most important parts of the research was the survey with coal experts. The survey results were analyzed using the constant comparative method.

The constant comparative method is one of the most important qualitative analyses in the grounded theory approach. The main tool of this kind of data analysis is comparison. It is the method of comparing and contrasting for all tasks throughout the analysis: creating categories, establishing the margins of the categories, and summarizing the content of each category (Boeije, 2002). The goal is to determine similarities and to discover the patterns. By comparing, the researcher is able to develop a theory by developing and connecting categories (Boeije, 2002).

I started the analysis of the survey data by looking at the interviews within coal industry group, as persons sharing the same background, role in coal sector, and experience. At the beginning of the analysis the comparison was conducted within each single interview. I studied every question of the interview to determine what exactly the respondent said and to mark each section. By comparing different parts of the interview I tested the consistency of the interview as a whole. The goal of this comparison was to develop categories. As a result I created a summary of each interview and I added a code to the specific parts of the interview.

When I discovered that all of the existing answers were identified I started to look for the sections which corresponded to my research questions.

At the end of the analysis I conducted a comparison of interviews from different groups of people – outside of coal industry. The goal of this comparison was to develop new concepts and points of view to develop the information of the first group (within coal industry) and to complete the analysis by giving the holistic and complete picture of the coal industry in Poland.

All responses were analyzed and included in the thesis. Two responses were unique and did not fit into any of the identified categories. They were reported as stated in the Appendix 2. Quotations were used to reflect the content of all the responses in each category and to illustrate more clearly the results. Finally, the charts, diagrams and tables were created to illustrate the data analysis outcomes. Microsoft Excel software was used to present the results.

Data analysis started in the field. Most of the responses were recorded; however in two cases recording was not possible. The participants were informed in advance about why recording is important and about issues around confidentiality and anonymity; however two respondents did not want the discussion to be audio-recorded. Their responses were recorded in the form of notes. I was prepared to be selective while writing the answers and notes and tried to collect data according to the research questions. After each day of interviews the responses were organized and the main points from the field notes were drawn. The answers recorded during interviews were transcribed during the days when the meetings were not scheduled.

The data analysis started after transcribing all of the data from the interviews, field notes and documents reviewed during the field work.

To analyze the data found in the documents content analysis was used, which allows viewing the literature source as a research resource and an objective indicator.

3.4 Conclusion on the Research Process

The research methods used in the research process were effective in achieving the objectives. Interviews with coal experts, attending meetings and conferences as well as the literature review were the best sources of the data, while field observations and informal discussion with coal miners brought to the research outcomes deeper understanding and wider perspective of the coal industry in Poland.

CHAPTER 4 Sustainable Energy Development in the Polish Coal Sector

In this chapter I provide an analysis of the outcomes of the study in relation to the objectives and themes generated from the survey with coal experts. It describes the legal framework of sustainable energy development in Poland and EU. It then examines the main environmental impacts of coal extraction and processing in Poland. Finally, I discuss the perspectives of applying clean-coal technologies in Poland and their implications for increasing the environmental sustainability of coal as an energy source. In order to provide a background I begin here with a brief explanation of Polish coal industry in terms of sustainable energy development.

4.1 Introduction

The geopolitical events of 2003 – 2006, especially the situation in Iraq, highlighted the fragility of the world's energy supply system. People started to pay more attention to energy supply disruptions and price volatility (World Energy Council 2004). According to World Energy Council (2004), unlike to oil and gas, coal supply will not be subject to significant price changes over the period of the next 30 years (Figure 6).

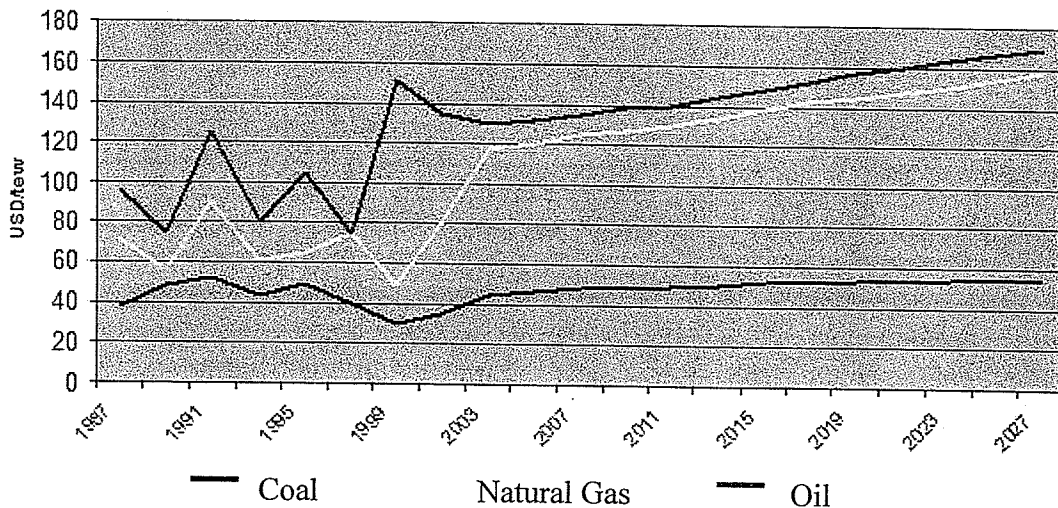


Figure 6 Actual prices of conventional energy sources and forecast for the next years (Source: World Energy Council, 2004)

Coal and other conventional energy sources are predicted to remain at the same high level as they are currently in the EU energy market (European Commission, 2004).

Under the Guidelines for Poland's Energy Policy until 2025 (Ministry of Economy and Labor 2005) as well as according to World Energy Council (2004) forecast, coal will continue to be the most important fuel in terms of electricity production in Poland.

According to the World Energy Council (2004), the energy demand as well as electricity demand in Poland will increase in the next decades (Figure 7 and 8). The expected growth of demand for energy, and particularly for electricity, may cause a significant increase of power sector demand for coal. Coal will still play the role of the main fuel for electricity generation in Poland and will contribute, as a main source of energy, in building energy security of the country (World Energy Council, 2004).

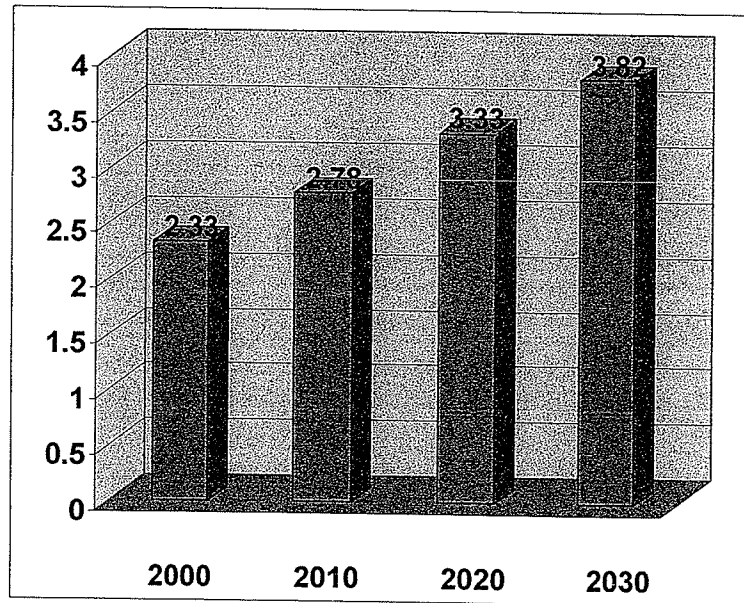


Figure 7 Outlook of primary energy demand in Poland per capita (toe/capita) (Source: World Energy Council 2004)

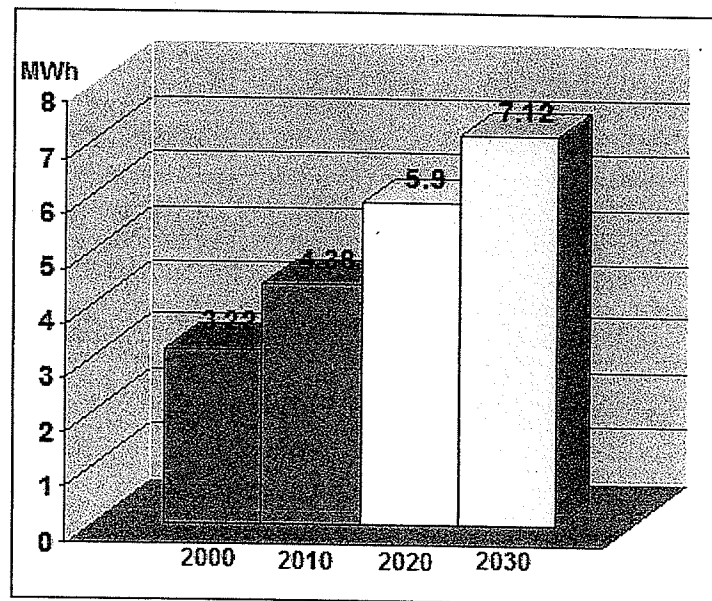


Figure 8 Outlook of electricity demand in Poland per capita (Source: World Energy Council 2004)

Coal can make a crucial contribution to energy security, but it has to improve its environmental sustainability. Sustainable energy development should be approached in

three dimensions – economic, environmental and social. Nowadays sustainable development describes the three dimensions as follows:

- 1) Economic sustainability includes the requirements for strong and long-lasting economic growth.
- 2) Environmental sustainability focuses on the stability of biological and physical systems and on preserving access to a healthy environment.
- 3) Social sustainability emphasizes the importance of well-functioning labor markets and high employment, of adaptability to major demographic changes, and of stability in social and cultural systems (OECD/IEA 2001).

Over the last fifteen years Polish coal mining industry has been put under pressure to improve its environmental performance. Since 1998 Polish mining sector has closed 32 coal mines (Ministry of Economy, Labor and Social Policy, 2004). Mining companies decided to undertake new programs of internal reform, which aim at achieving a serious change in the mineral sector. But to improve its environmental sustainability coal industry in Poland has to continue its effort in changing the sector especially in reducing greenhouse gas emissions and minimizing their effect on climate change.

4.2 Legal Framework for Coal in Sustainable Energy Development in Poland and EU

4.2.1 Regulatory Environment as a Supportive Tool for Building Coal in Sustainable Resource Use

To start considering coal in sustainable energy development in Poland, it is necessary to examine if current legislative structure in Poland and EU supports this initiative. According to coal experts, none of the acts or regulations speaks in favor of coal as a sustainable energy source. The regulatory environment considers mainly

renewable resources as a part of sustainable resource development. According to information obtained during survey, without legislative solutions promoting coal as a cleaner energy source, changes in this sector associated with improving coal's environmental performance would be much more difficult to realize.

The respondents identified three documents that might contribute to the integration of coal into a sustainable energy structure. There are the following: Green Paper - A European Strategy for Sustainable, Competitive and Secure Energy, 7th Framework Program of Research and Technological Development, and EU Program – The Technology Platform “Zero Emission Fossil Fuel Power Plants”.

In the Green Paper the European Commission indicates that an integrated global approach to climate change is a necessity. According to Piebalgs (2006), the Green Paper “A European Strategy for Sustainable, Competitive and Secure Energy” does not set the future of particular fuels, but it challenges each of them to prove that they can make an important contribution to EU sustainable energy development. From this perspective, the outlook for coal is more positive than it was in the last Green Paper “Towards a European Strategy for the Security of Energy Supply”. Current Green Paper recognizes that coal plays significant role in the EU's electricity production, due to reliable access to this source and to stable prices. The Green Paper, however, emphasises that to be considered as a sustainable energy resource, coal use must be accompanied by a reduced environmental impact, which means lower emissions (Piebalgs, 2006).

The Green Paper (2006) underlines the role of new technologies in achieving the sustainability objectives. For coal, this means developing clean coal technologies as well as carbon dioxide capture and storage.

Another document which supports sustainable coal industry development is 7th Framework Program for Research and Technological Development. It underlines the significant role of coal in the energy mix and examines the challenges facing this energy source in the context of a sustainable energy development. The Seventh Framework Program is created to support research area, in this case around clean coal technologies, by providing necessary funds.

The Technology Platform “Zero Emission Fossil Fuel Power Plants”, another program that coal experts identified as positive, has been developed by the European Commission Directorate General for Research with the support of groups of industrial associations. The European Commission, the European energy industry, researchers and non governmental organizations have established a European Technology Platform on Zero Emission Fossil Fuel Power Plants to bring together all key stakeholders to find solutions effectively minimizing emissions from utilization of conventional sources of energy (The European Commission, 2007). The scope of the Platform is to identify and eliminate the obstacles to create highly efficient, near-zero emissions power plants which may significantly reduce the environmental impact of fossil fuel use, particularly coal. This will include CO₂ capture and storage, as well as clean conversion technologies leading to important improvements in plant efficiency, reliability and costs (The European Commission, 2007). One of the interviewed coal experts, representing Polish scientists and industry in the Platform, underlined its importance in creating the base for clean coal technologies development and the fact that it is the first program of this kind in Europe, so far skeptical in promoting coal as a “clean” energy source.

4.2.2 Implementation of EU Directives in the Polish Coal Sector

Acts and regulations supporting coal in sustainable energy systems would be very important element of promoting this energy source. However, the current regulatory environment also sets emissions levels to which coal sector has to adjust. This issue was emphasized by coal experts during survey despite the fact that it was not included in the questions. As one of the survey experts representing “outside of coal industry” category said:

“The technological changes in the coal industry will be the result of more strict environmental laws and regulations. Currently the fines for polluting the environment are too low; from the economical point of view it is not profitable to introduce the technological improvements”

Since 1 May 2004, Poland has been a member country of the European Union. During the pre-accession negotiations Poland agreed to implement all EU regulations related to environment protection in the energy sector. Some EU documents (such as treaties and council regulations) are directly mandatory for all members, and some – such as directives – are obligatory in the target range and the member country chooses how to meet the target (Blaschke, 2004).

Adaptation of Polish legislation to European Union requirements is one of the most important elements of the process connected with the accession of Poland to that organization. According to one of the survey respondents from one of the scientific institute:

“Adapting Polish laws and regulations to EU requirements is a starting point in providing the appropriate changes in the coal industry”.

Directive 2001/81/EC on National Emission Ceilings for Atmospheric Pollutants (NEC Directive) and Directive 2001/80/EC on the limitation of emissions of certain

pollutants into the air from large combustion plants (LCP Directive) are the most connected with emissions related to coal industry.

The NEC Directive sets a country's limits for emissions of SO₂, NO_x, NH₃ and NMVOCs (nonmethane volatile organic compounds) (Blaschke, 2004). The LCP Directive prescribes the emission limits for large combustion plants, mainly for power plants. Its main target is to improve the environment and to create identical conditions of competitiveness in the European electricity market (Blaschke, 2004).

In Poland, because of very high percentage of solid fuels in the fuel mix the implementation of all requirements of the Directives would not be possible without some derogation (Blaschke, 2004). In Poland's Accession Treaty the following derogations for emissions are made for some power plants, CHP plants, industrial and district heating stations:

- SO₂ – 8 years;
- NO_x – 2 years; and
- particulate matters (PM) – 10 years (Blaschke, 2004).

Polish emission limits for sulfur dioxide and PMs are less restricted for existing plants than in the EU, but from 2016, when LCP Directive obligations come into force, the requirements will be the same (Blaschke, 2004).

The Second Sulfur Protocol obliges signatories' countries to reduce sulfur dioxide by the year 2010 to certain level. The protocol obliges Poland to reduce SO₂ emission (in relation to the basic year 1980) by 66% by the year 2010 (Blaschke, 2004). The main requirement resulting from the protocol is the total emission reduction from Poland's territory to the level of 1400 kt/a (Blaschke, 2004). New sources have to meet the

sharpest emission limits corresponding to the maximum level of desulphurization (90 percent: Blaschke, 2004). The largest existing sources (over 500 MWth) since 2004 should meet the same limits as new sources (Blaschke, 2004).

All described above documents and regulations force changes in the Polish coal industry. According to coal experts' opinion without improvements, especially in the technology area, Poland will not be able to meet the requirements.

4.3 The Main Environmental Impacts of Coal Extraction and Processing in Poland

According to surveyed experts, the key environmental challenges facing the coal industry are related to both coal mining – mainly the disturbance of land and the local environment and the use of coal – greenhouse gases, waste disposal, saline waters, dust pollution and ground settling. The main concerns identified by coal experts are presented in Figure 9.

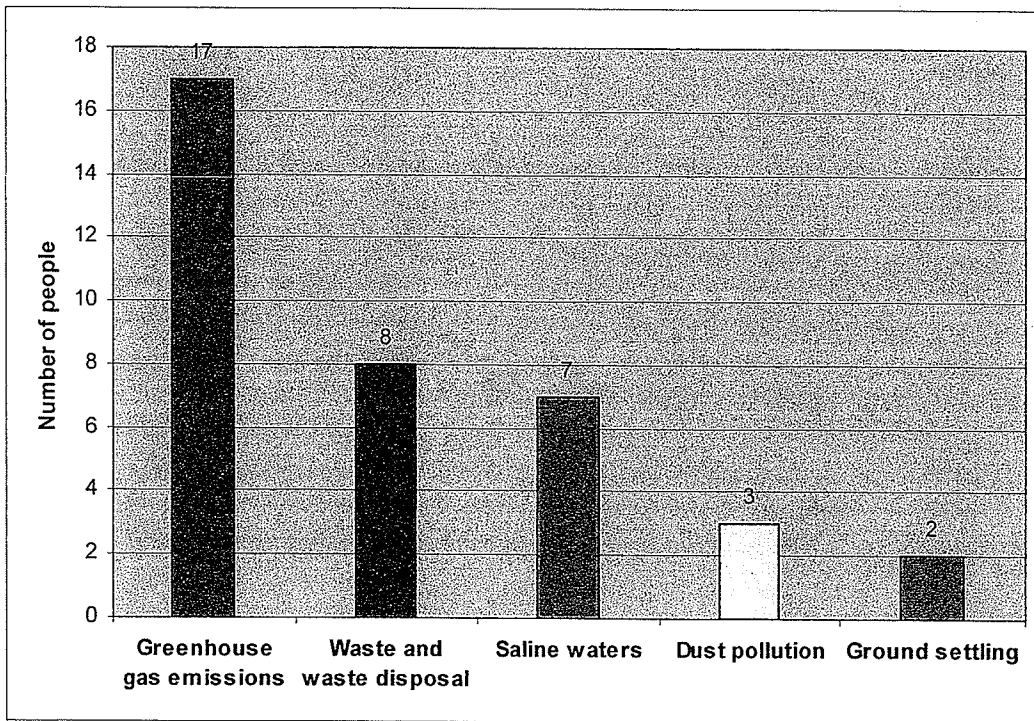


Figure 9 Main environmental impact of coal use in Poland according to survey coal experts

One of the experts representing one of the coal institutes and companies emphasized:

“Conventional energy, made during coal combustion is today the most common energy form. Coal plays the key role in European and world system of energy supply. In my opinion the situation will not change for the next decades. Exploration, transport, as well as processing of coal are related to the negative impact on the environment. There is no available technology which can eliminate that impact; however there are technologies which may significantly minimize impact on the environment.”

Further in the thesis, I will focus mostly on greenhouse gas emissions identified in the survey as the main environmental impacts associated with coal utilization in Poland. The problem of waste and waste disposal as well as saline water discharge related to coal use will be also described in context.

4.3.1 Waste from Exploitation of Coal

Eight survey respondents qualified waste and waste disposal from exploitation of coal as the most important problem to be solved in hard-coal mining industry in Poland. This point is also supported by Twardowska and Szczepanska (1999). According to them mining and the processing waste of hard-coal industry has been particularly heavy in the area of Upper Silesian Coal Basin and also the area of the Lower Silesian Coal Basin. In 2001 exploitation of hard-coal was accompanied by production of more than twenty thousand tons of mining waste (Twardowska and Szczepanska, 1999). More than fifteen thousand tons of this has been utilized in different ways (e.g. ground leveling, construction work, etc), while about 4,500 thousand tons were stored as dumps (Twardowska and Szczepanska, 1999). The coal waste is particularly hazardous for the environment, because the process waste from hard-coal enrichment and desulphurization technologies contains high amounts of pyrite (Twardowska and Szczepanska, 1999). Pyrite exposed to the atmosphere reacts with oxygen and water to form sulfuric acid, contributing to acid effect.

4.3.2 Saline Waters

Saline waters are another important problem identified in the survey as well as in the relevant literature to be solved in the Polish hard-coal industry. In the coal mining industry two main types of water can be distinguished: mine waters and saline waters.

Mine waters is a general name of waters pumped out from mines, i.e. waters which inflow to mine workings from the drained ground (natural inflow) and technological waters which inflow to mines (Rozkowski, 2000). Mine waters are highly variable in their chemical composition and total dissolved solids (Rozkowski, 2000).

Saline mine waters are waters in which the sum concentration of chloride and sulphate ions is more than 1800 mg/l (Rozkowski, 2000). The discharge of saline mine waters is an important source of surface water contamination in Poland, particularly in the Silesian province, where almost half of the rivers have too high salt content resulting from the discharge of saline mine waters into surface waters (Rozkowski and Rozkowski, 1994).

Saline mine waters cause the following environmental problems: rivers ability at self purification, losses in fishing stocks due to oxygen deficiency, concentrations above value of acute toxicity for some organisms, adoption of majority of fauna in relation to presence of sodium chloride, and increased number of species of certain groups of fauna.

According to Rozkowski (2000), the total amount of saline mine waters discharged into surface waters in the Silesian province has decreased significantly since 2000 as many coal mines have been closed. Current forecasts predict further decline in saline mine water discharge.

4.3.3 Greenhouse Gas Emissions

According to 17 surveyed coal experts, greenhouse gas emissions are the most important problem of fossil fuel combustion. One of them representing “within coal industry” category said:

“Considering sustainable development of coal use in Poland and its performance in terms of environmental impact the most important concern remains the emissions of greenhouse gases.”

And another from “outside of coal sector” added:

“The most important problem which needs to be solved in terms of coal impact on the environment is the problem of greenhouse gas emissions and its impact on climate change.”

Poland is considered to be one of the most polluted countries in Europe, mostly due to greenhouse gas emissions. Among the greenhouse gases are: water steam, ozone, carbon dioxide (CO₂), nitrogen oxide (N₂O), methane (CH₄), hydrofluorocarbons (HFC), carbon perfluorides, sulfur and fluoride SF₆ compounds and aerosols (Institute of Environmental Protection, 2002). The magnitude of gas emissions in Poland in standard units is presented in Table 2 (Institute of Environmental Protection, 2002, Warsaw). Table 3 presents greenhouse gas emissions from individual economy sectors in Poland in 1999 (Institute of Environmental Protection, 2002, Warsaw). It shows that the emissions of carbon dioxide and methane, associated with fuel extraction, are very high.

Table 2 Total emissions of greenhouse gases in Poland in 1988-2002

(Source: Institute of Environmental Protection, 2002)

		Year									Change in %	
Gas	Unit	1988	1990	1992	1994	1995	1996	1998	2000	2002	1998 base ^a	2000 base ^b
CO ₂	Tg	476	380	371	371	348	373	338	315	308	-35	-3
CH ₄	Gg	3141	2801	2474	2467	2457	2252	2335	2183	1800	-43	-3
N ₂ O	Gg	71	63	50	50	54	54	52	77	73	4	-5

a – using formula $([2002]-[1988])/ [1998]*100\%$, b – using formula $([2002]-[2000])/ [2000]*100\%$

Poland has one of the greatest shares of pollutants contributed by the fuel-energy complex and fuel combustion processes (Bialecka, 2003).

Greenhouse gases produced during energy conversion processes include:

- carbon dioxide: major contributor to the greenhouse effect;
- methane: released during coal extraction;
- nitrous oxide: emitted in small amounts during coal combustion (Bialecka, 2003)

Table 3 Greenhouse gas emissions in Poland in 1999**(Source: Institute of Environmental Protection, 2000)**

Specification	CO ₂ [Gg]	CH ₄ [Gg]	N ₂ O [Gg]
Energy total	326,963.2	874.1	7.4
Industrial processes	10,486.5	9.1	12.9
Agriculture	–	581.8	31.2
Land and forest use changes	645.1	0.2	0.0
Wastes	–	870.4	–
Total	338,094.8	2,335.5	51.6

Carbon dioxide is considered as the most important greenhouse gas. A similar situation occurs in Poland, where emission of this gas in 2002 was estimated at 308 276.89 kT (Tarkowski and Uliasz-Misiak, 2006). This emission mainly comes from industrial sectors of energy and industrial processes (Table 4). Ninety five percent of carbon dioxide emissions are linked to fuel combustion (Tarkowski and Uliasz-Misiak, 2006).

Nitrogen oxides generated in fuel combustion processes also significantly contribute to the climate change. The share of fuel combustion processes in nitrous oxide emissions is 14.3% (Bialecka, 2003). In the years 1985 to 1992 the total NO_x emissions in Poland were estimated at 1.5 to 1.53 Mt/year (Bialecka, 2003). Combustion of solid fuels for heat and power generation (about 50%) and liquid fuels were main contributors to this value (Bialecka, 2003).

Table 4 Emission of CO₂ from the energy sector in Poland in the year 2000

(Source: Institute of Environmental Protection, National Emission Centre, 2002)

Energy sector	CO₂ emission [Mt]	Share in energy sector [%]
Fuel combustion activities	302.29	
Energy industries	176.32	58.29
Manufacturing industries and construction	52.07	17.21
Transport	28.21	9.33
Other sectors	45.40	15.01
Other	0.29	0.10
Fugitive emissions from fuels	0.18	
Solid fuels	0.00	0.00
Oil and natural gas	0.18	0.06
Energy	302.47	100.00

Poland is also a country in which in coal-bed methane emissions are very high. In 1993, four percent of the world methane emissions were from the Upper Silesia Coal Basin area, located in the research project area (Nagy *et al.* 2006). The coal-bed methane emissions in 2002 amounted in that region to about 793,000 m³/year (Nagy *et al.* 2006). The emitted stream consisted of methane from coal-bed gas coal degassing, mine ventilation systems, diffusion release from mines, piles, storages and mine's installations (Institute of Environmental Protection, 2002). Literature and reports of environmental agencies give various data on CH₄ emission in the Upper Silesia Coal Basin (Nagy *et al.* 2006). The US Environmental Protection Agency gives the following data regarding emissions from coal mines in the Upper Silesia Coal Basin:

1. Methane from drainage operations 212.8 106 m³/year
2. Methane from ventilation air 540.7 106 m³/year
3. Utilized methane 167.7 106 m³/year
4. Methane emitted directly to the atmosphere 585.8 106 m³/year (Nagy *et al.* 2006)

This statement is supported by the data from Table 3, presenting greenhouse gas emissions from individual economy sectors in Poland in 1999. In the coal-based energy structure, the emissions of carbon dioxide and methane, associated with fuel extraction and energy generation, are very high.

4.3.4 Target Issues for Minimizing the Impact of Coal

The coal sector is the major source of emissions into the air of carbon dioxide, sulfur dioxide, and methane. Moreover, hard-coal mining causes changes to the landscape and material damage on the earth's surface. It also has a negative impact on water quality. Table 5 presents target issues for making coal use more environmentally sustainable identified during survey with coal experts. The activities which can build coal in sustainable energy development include implementing new technological solutions and implementing policy mechanisms improving coordination in coal mining industry and providing security of supply.

The answers for the question regarding improvements which can contribute to improving the environmental sustainability of coal use in Poland, in most cases were the specific technological and policy solutions in achieving the target issues (Table 6).

Table 5 Target issues for making coal use more environmentally sustainable

Target issues	
Technology	Introducing clean coal technologies Solving the problem of methane Removing sulfur from coal Improving efficiency
Policy	Providing energy security Improving coordination in coal mining industry
Other	Reclamation of dumps Improvement of safety in coal mines

Table 6 Target issues and improvements contributing to improvement of the environmental sustainability of coal use in Poland

	Target issues	Improvements
Technology	Introducing clean coal technologies	To improve the quality of combustion, to introduce CO ₂ sequestration, to introduce gasification (IGCC), powderized and fluidal technologies (supercritical and ultra-supercritical parameters), combustion of coal together with biomass
	Removing sulfur from coal	To increase the role of clean coal with low contamination of sulfur, to improve quality of coal
	Solving the problem of methane	
	Improving efficiency	
Policy	Providing energy security	To maintain stability of the system
	Improving coordination in coal mining industry	To increase cooperation between energy and hard-coal sectors, to allow wider vertical consolidation in coal industry
		To increase the level of individual customers
		To open Poland for imported coal
Other	Reclamation of dumps	

4.4 Clean Coal Technologies in Poland – Current Status and Future Perspectives

4.4.1 Introduction

As described above, greenhouse gas emissions are the most important problem for industry in Poland. Therefore, it is necessary to take advantage of technological improvements which may help to minimize coal's impact on the environment. Clean Coal Technologies, which may ensure meeting the standards of environmental protection, may be the solution. The term "clean coal technology" entered the energy vocabulary in the 1980s (Blaschke, 2004). It describes a new generation of advanced coal technologies, environmentally cleaner and in many cases more efficient and less expensive than conventional coal-burning processes. Equally important is the development of technologies which allow for storage and use of carbon dioxide from exhaust and for reducing the emissions of other greenhouse gases.

As identified in the survey, most of the respondents see the clean coal technologies development in Poland necessary to meet Kyoto and other national and international obligations. Figure 10 shows how surveyed coal experts, within and outside of coal industry, see the possibilities of introducing clean coal technologies Poland.

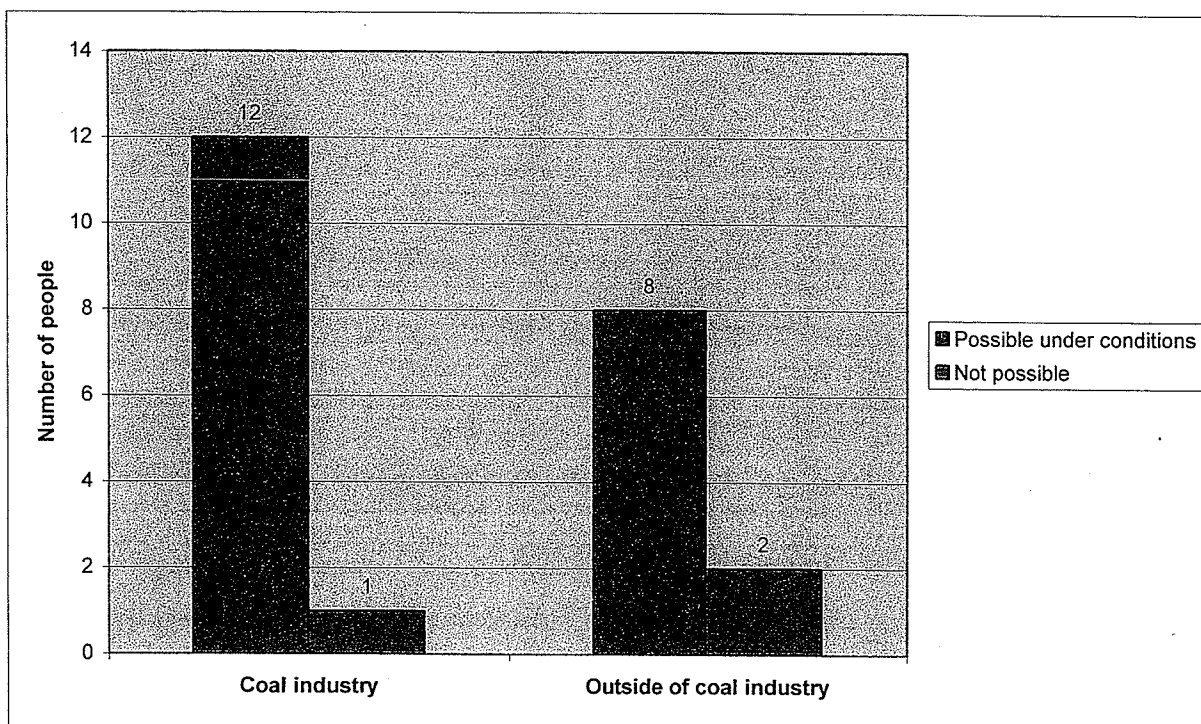


Figure 10 The possibilities of introducing clean coal technologies according to survey coal experts within and outside of coal industry.

The results presented above give “a green light” for clean coal technologies development in Poland. Most of the surveyed experts, from and outside of coal industry, agreed that it is a necessity. It is important however to mention, that those very positive opinions regarding the perspectives for technological change in Poland could be also the effect of the EU campaign in favor of clean coal actions which took place at the time of the interviews.

4.4.1 Clean Coal Technologies – Current Status

The wide program of modernization directed towards emission reductions started in the Polish power sector in the early 1990s (Blaschke, 2004). The clean coal-technology program in Poland started very late. The aim is to reduce air pollution in the process of coal combustion.

The program consists of:

- pre-combustion coal cleaning with hard-coal mix preparations in order to reduce air pollution and to maintain emissions limits (pre-combustion);
 - improvement of the combustion process, in order to eliminate harmful impurities (advanced combustion);
 - exhaust gases purifying (advanced post-combustion); and
 - new hard-coal conversions - gasification, liquefaction, pyrolysis (conversion)
- (Blaschke and Nycz, 2003).

4.4.2 Factors Limiting Clean Coal Technologies Development

The obstacles inhibiting introducing clean coal technologies in Poland identified by coal experts are presented in Table 7. Generally experts identified four main categories of barriers: technical, economic, related to policy issues, and other.

Within technical category the most often emphasized problem was the low interest of the power industry in buying coal of good quality. As one of the coal experts from universities and scientific institutes' category underlined:

“Nowadays talks about Clean Coal Technologies in Polish hard-coal industry are only empty talks. Today’s known clean coal technologies are used in a very limited scope. In Poland they only focus on adjusting quality parameters of coal to those from the signed purchase/sale agreements. And even those parameters are not achieved. At present, the biggest steaming coal users in Poland are not interested in buying good-quality coal. Coal users prefer to buy cheaper more dirty coal, because they use coal combustion technologies suitable for low quality coal”.

There are many reasons that there is little interest of the power industry in buying coal of good quality.

First, power stations built after the Second World War were adjusted for burning unprepared coal (called raw fine-coal). Those power stations had boilers adjusted to

burning coal of ash content between 20 and 35%. The power stations that were built later accepted even higher ash contents in coal. For this reason, there was no need to construct plants for fine-coal preparation. In those days, little attention was paid to the problem of environment pollution caused by burning coal of bad quality (Blaschke and Nycz, 2003).

Table 7 The obstacles inhibiting clean coal technologies development in Poland according to coal experts

CATEGORIES	BARRIERS
Technical	No interest in clean coal Specific kind of coal for each technology Lack of skilled workers
Economic	Lack of finance
Policy	Lack of people taking the initiative Lack of adequate law system – acts and regulations Lack of decision makers Interests of particular sectors Lack of consortium Social cost
Other	Psychological Barriers Political beliefs Bad perception of coal NGO`s

The modernization of power stations and thermal-electric power stations that have been introduced in the last few years did not bring significant changes to this process. In the most cases, coal with ash contents between 18 and 25% was burned (Blaschke and Nycz, 2003).

In summary, as one of the survey respondents from “outside of industry” said:

“Clean coal production mostly depends on quality demands of customers. If they are not interested in buying clean coal, mines will not produce it”.

Another technical barrier identified in the survey was the problem of specific kind of coal suitable for particular clean coal technology. As experts emphasized, every technology is constructed for the specific coal parameters and only locations having those kinds of coal should be taken into account as the perspective place for further clean coal technologies development. So far only a few locations have been identified, but still more research is needed regarding feasibility of the future projects.

Coal experts emphasized also that the employment reduction in coal industry in Poland may be the limiting factor for clean coal technologies development. Highly qualified mining engineers are already retired and new students are not interested in coal related professions, because of job finding problems in the sector which is being restructured. A few schools were closed because of these reasons. It will take time to gain the interest of new students and then trained them not only in Poland but also abroad to get the appropriate qualifications. As one of the expert representing coal companies and institutes said:

“Another problem, which is the effect of enormous employment reduction in Polish hard-coal sector, became the shortage of mining personnel and highly qualified staff which would be responsible for clean coal technologies demonstration projects”.

The financial problems as well as lack of adequate law system – acts and regulations, and lack of people taking the initiative – decision makers were also emphasized as the key issues which have to be solved in order to apply clean coal technologies in Poland.

Survey experts agreed that

“There is no technological limitations for development and competitiveness of clean coal technologies in Poland and worldwide. There are only economic limitations: lack of finance sources, not clear perspectives regarding potential loans payments, as well as possible lack of competitiveness of the products made by using energy and heat from clean coal plants.”

The above mentioned barrier is also presented in the literature. According to Brendow (2004), the major obstacle of equipping coal-based power generation with clean coal technologies is financing.

Lack of adequate law system – acts and regulations were also identified by the coal experts as a barrier against introducing clean coal technologies in Poland. The actual system does not enhance development and demonstration projects of clean coal technologies (for example: lack of tax rebate policy for companies or investors who decide to implement advanced technologies).

The most important obstacles inhibiting clean coal technologies development identified by the surveyed coal experts can be also found in the literature. European Parliament (2003) recognizes barriers in applying clean coal technologies. For example, advanced power plants have high initial investment costs, and their development is expensive. Also the risks associated with innovative technologies and their potential environmental impacts may discourage investors, and make it difficult to finance them. As one of the coal experts from coal institute underlined:

“Analyzing feasibility of introducing coal gasification technologies we have to remember that so far in the long coal processing history, those processes were successfully developed in a large industrial scale only in two countries: in the Third Reich (because of lack of liquid fuel during Second World War) and in the Republic of South Africa (because of an embargo on the oil). Implementing these complex and expensive technologies in the free market, where coal has to compete with oil and gas and their very high price volatility, always brings fear among the potential investors. In this regard it is necessary to make appropriate decisions based on deep economic and technical

analysis. The main “pro” for taking the action and implementing new clean coal technologies in Poland is definitely the fact of having significant coal reserves. Furthermore it will allow increasing energy security of the country.”

According to European Parliament (2003), aspects of market operation, relevant regulations and lack of an appropriate infrastructure may limit or prevent deployment of clean coal technologies in certain cases.

Another factor limiting clean coal production identified in the survey was the interest of particular sectors. In the EU market there is competition between technologies within the heat and power sector. The natural gas technologies development has very strong support among EU countries. The proponents of coal development are in the minority. However, the aspect of the stability of the fuel price has to be considered in the long term view of using coal for large scale power generation. The fuel price volatility of natural gas makes the long-term investment in gas fired power plants expensive, while the coal as a fuel price is calculable, stable and low in the long-term (European Parliament, 2003).

Coal experts also mentioned lack of consortium of manufacturers, operators and research institutes involved in clean coal technologies development as an obstacle inhibiting the technological improvements.

Among other obstacles interviewers pointed out psychological barriers and bad perception of coal. Psychological barriers are very important issues in planning clean coal technologies development in Poland. As mentioned earlier in this report technological changes, especially those being at the demonstration stage of development, are associated with some risk. Among politicians that risk is even higher, because undertaking the steps to make the improvements they are aware that in the case of failure it may impact their

careers. It results in hesitating when making the key decisions regarding expensive technological shifts in hard-coal industry.

Bad perception of coal was also underlined by surveyed people as an obstacle inhibiting clean coal technologies development. The public considers coal industry as a dirty sector and any technological improvements, according to them, will not change this fact. As one of the respondents from “outside of coal industry” said:

“Coal mining in Poland outside of the Silesia region is considered as an unprofitable, dirty sector. It results from bad perception of coal industry presented in the mass media and in the interviews with politicians. They emphasize negative impact on the environment while region degradation is not caused by the industry itself, but because of the use of low quality coal. But the fault is considered to be on a mining side”.

In the researcher opinion however, the media in Poland plays an important role in presenting the problems related to coal use as well as in informing the public regarding changes and improvements undertaken in the coal sector.

4.4.3 Clean Coal Technologies for the Future Use

Technological improvements have the potential to extend the range of coal utilization. Moreover, clean coal technologies can help mitigate environmental side effects associated with the coal cycle (Fay and Golomb, 2002).

A basic approach to the cleaner use of coal is to reduce emissions of CO₂, SO₂, NO_x and cleaning the flue gases after combustion. A parallel approach is to develop more thermally efficient systems so that less coal is used to generate the same amount of power (Urge-Vorsatz, 2003).

According to International Energy Agency (1997), stabilizing greenhouse gas emissions will require changes in the way we produce and consume energy products. These changes may be partially behavioral, but will be mainly technical.

Various methods for coal-fired power generation are being developed, and different steps are being taken to improve environmental performance of coal. Clean coal technologies are undergoing development in order to provide an environmentally acceptable method of using coal as a basic fuel for power production in new plants. Some are now commercially available, but most of them are still at the demonstration stage.

To date there are four major power plant concepts based on coal combustion which are either commercially available and are being developed further or are in an advanced development phase with first demonstration projects under way (European Parliament, 2003).

4.4.3.1 PCF - Conventional Pulverized Coal Fired Technology

The conventional pulverized coal fired technology (PCF) is based on a pure steam cycle process. This is the major technology of the past 50 years and new power plant designs utilizing supercritical steam conditions (about 580°C/280 bar) can reach net efficiencies of 40-45% (up to 47% for sea water cooled power plants) (European Parliament, 2003). The most modern technologies achieve burnouts of 99 per cent of the carbon (International Energy Agency, 1997). Much research and development focuses on the further development of this technology in Europe, the US and Japan to increase efficiencies by up to 50% with the introduction of ultra supercritical (USC) steam technology. The investment costs of modern PCF are in the range of 800-1000 Euro/kW with desulphurization (European Parliament, 2003).

4.4.4.2 FBC - Fluidized Bed Combustion

Fluidized bed combustion (FBC) also is based on the use of coal as a fuel. It uses a wide variety of coals, including lower-grade fuels. It also allows for fuel co-combustion

with biomass or for coal blending (European Parliament, 2003). This technology allows in-furnace removal of sulfur and, because of lower combustion temperatures, reduced production of NO_x emissions (International Energy Agency, 1997). Two major types of this technology are on the market depending on the pressure in boiler: atmospheric circulated fluidized bed combustion and pressurized circulating fluidized bed combustion (European Parliament, 2003).

The boiler of an atmospheric circulated fluidized bed combustion (AFBC) power plant is operated at ambient pressure either in a circulating (CFB) or a bubbling fluidized bed (BFB) (European Parliament, 2003). The use of a circulating fluidized-bed (CFB) for power generation is a rapidly growing technology in Poland. The ability of CFBs to burn a wide variety of fuels, while meeting strict emission-control regulations, makes them an ideal choice for burning such fuels as high-sulfur coal, lignite, oil, and petroleum coke (Nowak, 2003). All these fuels are burned economically in CFB boilers without the need for complex scrubbers, catalytic systems or other expensive chemical clean-up equipments (Nowak 2003). Presently 19 CFB units are in operation or under construction in Poland, utilizing a wide variety of fuels. On the basis of collected data, the CFB units successfully met all the emission levels (Nowak, 2003).

The AFBC type is widely in use (about 300 units in the world) and fully developed and commercially available. AFBC is an attractive alternative to PCF technology, when low cost solid or liquid fuels are available (European Parliament, 2003). Net efficiencies of AFBC are in the range 38-40%. Power plants of 200-300 MW class are available, 500-600 MW are designed (e.g. from Lurgi) (European Parliament, 2003)

Pressurized fluidized bed combustion (PFBC) is relatively new on the market with its first demo plants in early 1990s (European Parliament, 2003).

PFBC technology is a development of the atmospheric fluidized bed technology (AFBC). PFBC plants, unlike the AFBC plants, use a combined gas and steam cycle (European Parliament 2003). PFBC plants operate at pressures ten times or more above atmospheric and this allows the introduction of a gas cycle and an increase in unit power output (International Energy Agency, 1997).

PFBC has the technical potential to achieve high net efficiencies 40-42%. It is possible because the hot flue gas is directly fed into a gas turbine due to the high pressure in the boiler. With some improvements of this technology future efficiency is estimated to reach 47% (European Parliament 2003). Through using PFBC also very low emissions of SO_x and NO_x can be accomplished (International Energy Agency, 1997); however according to European Parliament (2003), the high degree of integration and the low availability of some key components did not allow this technology to come out from the demonstration stage and be commercially competitive.

4.4.4.3 IGCC - Integrated Gasification Combined Cycle

IGCC technology is a combined cycle based on coal gasification and combustion of syngas in a gas turbine (European Parliament, 2003). IGCC uses synthesis natural gas obtained from a coal gasifier to drive the gas cycle. The overall net efficiency of this technology is about 42-45%, but it is expected to be increased to 50-52% in the future (European Parliament 2003). In using IGCC, similarly to PFBC, it is possible to use lower quality fuels and still get competitive net efficiencies (International Energy Agency, 1997). Emission control is done in two ways: is integrated into the boiler and

connected with the syngas cleaning. It allows for very low emissions of SO_x and NO_x (European Parliament, 2003). The investment costs are currently at about 1500-2000 Euro/kW (European Parliament, 2003).

As one of the experts representing coal companies and institutes pointed out:

“Basic processes of energo-chemical coal conversion are as follows: carbonization, hydrogenation and gasification. Carbonization of hard-coal constitutes the most widely spread technology option binding generation of energy carriers and chemicals. Particularly it is applied to coke production and its by-products like coal tar and coke oven gas. Gasification is regarded as a basic process for advanced concepts of future coal conversion technologies. At present the process is widely used in chemical industry mainly for petrochemical by-products conversion, but only occasionally for power generation as demonstration plants.”

IGCC technology is commercially available, but it is still under continuous development and improvements. Two main IGCC demonstration projects in the EU were the IGCC projects at Buggenum (Netherlands) and Puertollano (Spain). In the US there are currently three major IGCC demonstration plants already in operation (European Parliament, 2003).

IGCC is currently not the best commercially competitive technology for power generation, because of the high investment costs and the low operation availability (European Parliament, 2003). However, carbon dioxide removal from IGCC is significantly less expensive than its removal using conventional power plant technology (International Energy Agency, 1997). Therefore, this may become a commercialization path in the future.

4.4.4.4 Clean Coal Technologies at Early Stage of Development

All the above mentioned clean coal technologies used for power generation are commercially available or under continuous development with demonstration projects under way. The following are the technologies that have not yet been commercially available:

1. PPCC- Pressurized Pulverized Coal Combustion

PPCC, similarly to PFBC, uses a combined cycle with both a pressurized boiler unit and a gas turbine for the direct utilization of the flue gas (European Parliament, 2003).

PPCC technology is presently at a development stage with small pilot plants. PPCC boilers and flue gas clean-up systems are being operated at research centers mostly in Germany. There is no detailed data available regarding efficiencies and emissions levels achieved through using this technology; however efficiencies of 55% are expected to be possible (European Parliament, 2003).

2. IGFC - Integrated Coal-Gasification Fuel Cell Technology

This clean coal technology is at an early stage of development. Currently there are two major projects in the US and in Japan (European Parliament, 2003).

IGFC technology uses electro-chemical cycle. Fuel cells are devices that convert chemical energy directly into electric energy. They use a coal gasifier and gas cleanup system to supply a methane-rich gas to the fuel cell stack (International Energy Agency, 1997).

IGFC has the technical potential to achieve very low emissions of SO_x and NO_x and efficiencies as high as 60% (International Energy Agency, 1997). To date no qualified expectations for overall system costs of IGFC are possible. According to International Energy Agency (1997), major technology development has to be completed before this technology can be commercialized.

It is estimated that first demonstration power plants with capacities in the utility range (300 MW fuel cell plus 300 MW gas and steam) will be implemented around 2020 (European Parliament, 2003).

The only two projects currently underway are the US funded Kentucky Pioneer IGCC Demonstration Project and the EAGLE project in Wakamatsu, Japan. They are more IGCC related projects with the additional testing of fuel cells (European Parliament, 2003).

3. MHD - Magneto Hydrodynamic Power Generation

In MHD, a high-temperature combustion gas stream is passed through a strong magnetic field to generate electricity (International Energy Agency, 1997). MHD is a prospective technology, because of its potential to achieve thermal conversion efficiencies more than 50% and low pollutant emissions; however, MHD power generation deployment will take many years even if further research and development efforts are undertaken (International Energy Agency, 1997).

Research of magnetohydrodynamic power generation was originally the part of the US MHD program but was stopped. Only the area around low-NO_x burner development part of the MHD program is being researched (European Parliament, 2003).

4.4.4.5 Comparative Analysis of Different Available Technologies

As emphasized throughout this report clean coal technologies give the opportunity to minimize the impact of coal use on the environment. The problem, however, is to choose the best available technologies in the Polish case.

According to International Energy Agency (2006) and interviewed coal experts, in considering each clean coal technologies for implementation in Poland the following key factors should be considered:

- the overall economics of plant construction and operation;
- the kind and cost of the coal used;
- the effectiveness with which new units can meet environmental requirements,
- the thermal efficiency of generation, which influences directly CO₂ emissions;
- emissions levels achieved by using the technology;
- effects of the technology implementation in the large scale projects; and,
- the state of development of the technology (International Energy Agency 2006).

As one of the surveyed expert from the universities and scientific institutes' category emphasized:

“To find the best technologies for Poland it is necessary to choose the technologies which are well known, proven and used on the large scale. We have to have a point of reference before making a decision. Without it our potential solutions regarding clean coal technologies development in Poland will remain only theoretical solutions and there will be understandable fear of implementing them. We have to know the economic calculations and effects of implementation in the large scale projects.”

And another representing coal company added:

“Making the choice of the appropriate technological solutions we have to take into account the quality of coal being used, its accessibility, but also actual market demands for the specific products. At the same time it has to be maintained high availability and reliability of the equipment accompanying by acceptable investment as well as energy

production costs. In every case it is necessary to undertake deep economic and technical analysis”

According to surveyed experts, two main streams of clean coal technologies development in Poland should be considered. First one are sub- and supercritical PC and FBC based technologies which have a realistic potential for further development in the short and medium term. The second stream should be represented by IGCC technologies, giving the possibility for the electric and chemical energy production which will play a role in the long-term perspective.

First of all, choosing the supercritical coal technologies coal experts took into account their availability and the fact that they have been tested at the commercial large scale. The supercritical coal power plant achieves high conversion efficiencies by applying supercritical steam conditions (higher pressure and temperature of the steam). According to European Parliament (2003), the conversion efficiency is going to be increased to 49% in 2030. The capital cost of the technology is approximately 1450-1700 US\$/kW with relatively low operating and maintenance costs. The achievable emissions reductions in case of SO_x are 90-95% and NO_x – 60-70%.

According to coal experts, selecting technologies using supercritical conditions is linked to still not very high effectiveness of chemical enthalpy of conventional combustion.

Another argument in favor for choosing FBC-based technologies is the fact that a number of FBC-based units are now operational or under construction. According to one of the surveyed experts from coal institute:

“It is more economical to install CFBC technology than to install low NO_x burners and FGD systems in outdated PF plants.”

CFBC projects are in place at a few Polish locations, for example Turow, Katowice, Jaworzno, Chorzow, and Zeran. Individual unit capacity is in the range 60-260 MW and 30-15 MWth (International Energy Agency, 2003). The installation of those technologies has resulted in reduced emissions, improved plant reliability, increased overall efficiency and increased output (International Energy Agency, 2003).

Another technology selected by coal experts was the integrated coal gasification combined cycle (IGCC). This technology applies coal gasification with combustion of the coal gas in a gas turbine. The technology is going to reach about 50% efficiency and costs 1350 Euro/kW by 2030. The operating and maintenance costs will be about 87 Euro/kW (European Parliament, 2003). The emissions reductions are very high and remain at the same level as in the supercritical FBC-based technologies.

According to analysis done by Institute for Chemical Processing of Coal (2006), presented in Table 8 and Table 9, IGCC technology allows to achieve higher net thermal efficiencies than coal combustion in pulverized boilers; however, currently available pulverized combustion technologies, sub and supercritical, also make it possible to reach efficiencies at the similar level. Significant differences can be also seen in the case of CO₂ removal. Coal gasification offers much better results.

It is also important to mention that in IGCC technology broad variety of coals can be used. What is even more important; the biomass also can be utilized. Thermal efficiency achieved through IGCC when using coal of low quality is about 45%, but when high quality coal is utilized and advanced gas turbine are used the efficiency rises to about 48-50%.

Table 8 The parameters of coal combustion in different configuration of pulverized boilers (Source: Institute for Chemical Processing of Coal, 2006)

Parameters	COAL COMBUSTION IN PULVERIZED BOILERS		
	Coal combustion + steam turbine	Coal combustion + steam turbine + CO ₂ removal	Oxyfuel combustion + steam turbine + CO ₂ removal
Net Power MWe	396.8	283	298.4
Net efficiency, %	39	28	31
Investment cost, \$/kWe	1268	2373	2259
Electric energy cost, \$/MWh	42.3	76.6	68.8
NO _x emission, kg/MWh	2.04	2.87	0.102
SO _x emission, kg/MWh	1.56	2.0	1.49
CO ₂ emission, kg/MWh	918	64	
CO ₂ reduction, kg/MWh		1224	1166

Table 9 The parameters of different coal gasification systems (Source: Institute for Chemical Processing of Coal, 2006)

Parameters	INTEGRATED GASIFICATION COMBINED CYCLE		
	Coal gasification + cold gas cleaning	Coal gasification + hot gas cleaning	Coal gasification + cold gas cleaning + CO ₂ removal
Net power MWe	400.6	400.4	358.6
Net efficiency, %	47	49	40
Investment cost, \$/kWe	1374	1354	1897
Electric energy cost, \$/MWh	40.9	39.1	54.4
NO _x emission, kg/MWh	0.165	0.165	1.185
SO _x emission, kg/MWh	0.342	0.04	0.113
CO ₂ emission, kg/MWh	1517	1431	231
CO ₂ reduction, kg/MWh			1536

The coal experts also very often emphasized that one of the advantages of the coal gasification is production of methanol. The typical answer was:

“In our situation the best solution seems to be introducing proven clean coal technologies. It may be for example demonstration power plant, using Integrated Gasification Combined Cycle, producing electricity and methanol at the same time.”

According to interviewers and International Energy Agency (1997), coal gasification plants can be designed to co-produce a combination of two or more end-products, raising efficiency to more than 60%.

Table 10 Comparative analysis of parameters achieved in IGCC and combined IGCC and methanol production (Source: Institute for Chemical Processing of Coal, 2006)

Parameter	IGCC	IGCC + methanol production
The amount of coal, tons/year	793 500	793 500
The production of electric energy, MWh/year	2 000 000	1 368 000
The methanol production tons/year	-	218 840
CO₂ emissions tons/year	1 789 360	1 488 439
Efficiency %(electric energy + methanol)	40	51
The cost of building installation, thousand USD	391 960	407 170

From the data presented in Table 10, it can be observed that integrating methanol production into IGCC system energy production allows improving thermal efficiency and reducing CO₂ emission. It is connected with higher efficiency of chemical synthesis. The combined system (IGCC+methanol production) might be also profitable because of gradually rising prices of methanol on the world market (Figure 11).

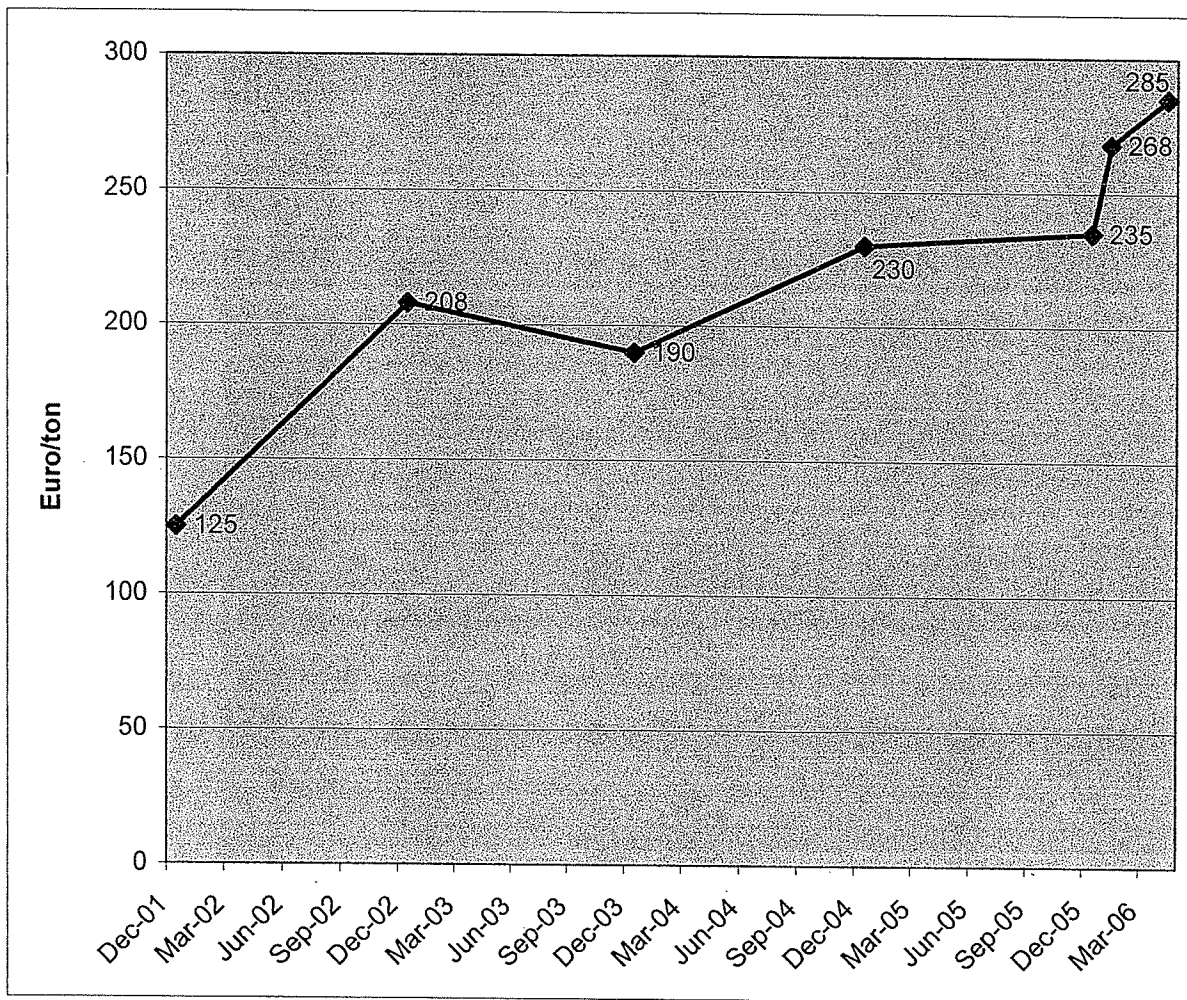


Figure 11 The prices of methanol on the world market in the years 2001-2006 (Euro/ton)
 (Source: Institute for Chemical Processing of Coal, 2006)

The most important problem, according to coal experts, is however CO₂ emissions. Costs associated with applying technologies minimizing those emissions will lead to increase in the costs of energy production. The costs of energy production, taking into account CO₂ sequestration, are presented in Table 11. The data show that the cost of electric energy generated by using IGCC technologies is the highest; however when we consider CO₂ capture technologies combined with IGCC the cost of energy is lower than CO₂ capture integrated with pulverized combustion.

Table 11 The cost of electric energy production with and without CO₂ removal

(Source: Institute for Chemical Processing of Coal, 2006)

The technology used to produce the energy	The costs of electric energy production				
	Without CO ₂ removal		With CO ₂ removal		
	Average	Range	Average	Range	Increase in the costs
Pulverized combustion, U.S. Cents/kWh	4.5	3.9-5.3	7.7	6.4-8.7	71%
IGCC, U.S. Cents/kWh	4.8	4.1-5.8	6.6	5.5-8.3	37%
NGCC, U.S.Cents/kWh	3.1	2.3-3.7	4.6	3.5-5.8	48%

The technological improvements in Polish coal sector, even if increasing the final cost of energy, are necessary. Most of the power units in Poland have been used for more than 30 years. According to Laudyn *et al.* (2005), who did the analysis of the equipments of the existing power plants in Poland, power units of 120 MW were last installed in 1970, so they have been operating for more than 30 years and 11 of them exceeded 35 years. Among 57 units of 200 MW, 44 have been using for more than 25 years, and 18 for more than 30 years. The same situation applies to the 360 MW power units. They have been operating for more than 20 years. The interviewed coal experts said that it is not applicable and profitable to modernize power units older than 35-40 years by installing low NO_x burners and FGD.

According to coal experts, it is necessary to replace outdated power units and replace them with new equipment. Therefore, it seems reasonable to consider new clean coal technologies, giving the perspective for more efficient and low emissions power generation.

Interviewed coal experts emphasized also that it is very important to undertake deep research and to do an analysis in every case when planning clean coal technology implementation. Location of the power plant, coal availability and accessibility, as well as waste disposal should be taken into account when making the feasibility plans.

4.4.4.6 The Assessment of CO₂ Capture and Sequestration Methods Suitable for Poland

Carbon dioxide sequestration is another option for reducing greenhouse gas emissions in the power sector. Capturing, transporting and storing are the elements of underground storage of CO₂. The most expensive part is CO₂ capture. The costs of transport depend on the distance from the source of emission to the storage place (European Parliament, 2003). According to Tarkowski (2005), the costs of injection remain the lowest and depend on the volume of CO₂ injected and the depth of reservoir. The high costs of CO₂ capture are the main reason why underground storage is not in common use (Tarkowski, 2005).

According to coal experts and European Parliament (2003), there are three main technologies of CO₂ capture available on the market: post-combustion scrubbing, pre-combustion technologies, and oxyfuel.

Post-combustion scrubbing is considered as the first step towards large-scale capture. CO₂ is removed from exhaust gas after combustion. This technology can be retrofitted to existing installations of PCF-advanced power technologies (European Parliament, 2003).

Pre-combustion technologies are the decarbonization technologies using natural gas as a fuel which is converted to hydrogen and CO₂ in a reformer. The CO₂ is

compressed for storage and the hydrogen is mixed with air for combustion, emitting only nitrogen and water (European Parliament, 2003).

Coal gasification, as used in IGCC plants, can be also seen as a pre-combustion technology. If air is used for the combustion, the exhaust gas is enriched in CO₂ and water vapour (later could easily be separated), which could be stored using any storage technology (European Parliament, 2003).

In the oxyfuel technology, oxygen is separated from air and then burned with hydrocarbons to produce an exhaust with a high concentration of CO₂ for storage (European Parliament, 2003).

Carbon dioxide capture is a first step in the sequestration; the next step is carbon storage. Storage must be characterized by a low environmental impact, acceptable costs and accordance with national and international laws. The main options for storing CO₂ underground are in deep saline reservoirs, unminable coal seams, and depleted oil and gas reservoirs (European Parliament, 2003).

The perspective of sequestration of CO₂ by underground storage is also considered in Poland. This is reflected by ongoing research on possibilities to store this gas in deep-seated geological oil and gas reservoirs and aquifers (Tarkowski, 2003).

Furthermore, studies researching the conditions for building a pilot installation for underground storage of CO₂ in an abandoned hydrocarbon deposit are being carried out (Tarkowski, 2005).

Geological structures suitable for disposal and storage of CO₂ should be appropriately tight and large, without hydraulic connections with either exploited fresh water horizons or aquatic systems that might be exploited in the future (Tarkowski,

2006). Such requirements may be matched by structures located in deep seated saline aquifers. Carbon dioxide can be stored in huge quantities in deep saline aquifers. Interesting issues of this method are associated with the long-term stability of those systems, safety aspects, and public acceptability (European Parliament, 2003).

The method of storing CO₂ in the aquifers is also considered in Poland. Tarkowski (2006), who analyzed the power and industrial plants with major CO₂ emissions in Poland and the possibilities of finding sites suitable for CO₂ sequestration from those plants, found that there are some geological media applicable for the storage. This is particularly valid for deep aquifers related to Lower Cretaceous, Lower Jurassic and Lower Triassic sedimentary series within Polish Lowlands. Considering location of 53 major CO₂ emission point sources, he chose 17 structures which may be used as sites for CO₂ sequestration by underground storage. The structures are situated close to 18 of the major emission point sources mentioned above power and industrial plants.

Total surface of the areas suitable for CO₂ storage in Polish Lowlands identified by Tarkowski are as follows:

- in the Lower Cretaceous aquifer-about 15 100 km²
- in the Lower Jurassic aquifer-about 53 100 km²
- in the Lower Triassic aquifer-about 122 020 km² (Tarkowski, 2006)

Coal beds are another place where CO₂ can be stored. CO₂ can be injected into deep un-minable coal beds. Poland has experience in underground injection and storage of acid gases, because it participates in the EU RECOPOL Project, aimed at testing possibilities to inject and store CO₂ in deep non-exploitable coal seams. This successful research project has lately come to an end. RECOPOL project was developed as a

demonstration project. This pilot installation was developed for methane gas production from coal beds while simultaneously storing CO₂ underground. This installation is first of this kind in Europe, and at the moment the only one operational worldwide (Tarkowski, 2006). According to one of the surveyed experts, responsible for this project, several months of injection showed that injection without stimulation is difficult under the local field conditions. The experience gained during this operation can help to overcome start-up barriers of future CO₂ sequestration initiatives in Europe and be a good starting point for future actions in Poland.

Depleted oil and gas reservoirs, combined with enhanced oil or gas recovery, are another way to store CO₂. CO₂ can be used to replace or displace additional oil or gas from a depleted reservoir. Studies are required on topics such as process, stability, public acceptance, and injection and dispersion techniques (European Parliament, 2003). Those studies were carried on in Poland too. According to them, for underground storage of CO₂, four oil reservoirs and 19 gas reservoirs were chosen (Tarkowski, 2005). The pilot project using this kind of method was recommended. The scientists found no interaction between rocks of the reservoirs (sandstones) and CO₂. Detailed studies of these geological structures are in progress and should form the basis for further selection of the best sites for CO₂ sequestration in Poland.

Other method of CO₂ storage is deep oceans storage; however this method does not have perspectives for development in Poland because of the geographical conditions (no deep oceans located in that area).

The CO₂ capture and storage methods are very promising options for emissions reductions, however more research is needed regarding the possibilities of applying them as well as regarding the cost associated with CO₂ sequestration.

4.4.5 The Opportunities of Technologies Development Financing in Poland

Clean coal technologies may be the option for incorporating coal into sustainable resource development in Poland; however very important, if not the most important problem - rising funds for research, demonstration projects, and finally future commercial large scale initiatives must be solved.

According to coal experts besides state budget, Poland has to take advantage of being part of EU, currently interested in finding new, more environmentally sustainable ways of coal use. Very important is also involvement of coal companies and their participation in the costs.

As identified in the survey:

"In our [Polish] situation the best solution seems to be introducing clean coal technologies through using state funds, EU co-financing, and companies' funds – potential suppliers of equipment for the known and proven technologies. It may be for example demonstration power plant, using Integrated Gas Combined Cycle, producing electricity and methanol at the same time."

It is however important to mention, that bringing the question during the survey: "Is there any public support for stimulating development in mining technology, coal preparation and coal conversion, as well as research and demonstration projects in coal combustion and gasification in Poland?" I got results showing that almost half of the respondents (10) either do not know about the financial sources or state that there is no support. Most of the respondents not aware of financial possibilities come from coal companies and coal associations. The interviewers from government and governmental

agencies and academicians had the best knowledge about the available support. This result calls for developing better information flow around financial programs existing in the field of coal technologies development.

According to coal experts as well as Ministry of Environment (2006) the development of environmental technologies, including clean coal technologies are financed by a few sources.

One of them is VI Framework Program of the European Community for Research, Technological Development EU, and since the year 2007 resources of VII Program. Within the framework of the VI Framework Program research and development projects are co-financed by the European Committee and the group of the institution called the consortium. Besides research works, results of projects and accompanying activities are also financially supported.

Clean coal technologies are also part of the VII Framework Program of the EU. The aim of this initiative is to improve plant efficiency, reliability and cost by using research, development and demonstration plants of clean coal technologies (Ministry of Environment, 2006). One of the main research projects within the VII Framework Program is mentioned earlier “Technology Platform for Zero Emission Fossil Fuel Power Plants”.

There are also European Coal and Steel Community funds for the research in the coal and steel industry, from which clean coal technologies could be financially supported. These funds are called “Research Program of the Research Fund for Coal and Steel”.

Implementation of the environmental technologies is also co-financed by National Fund for Environmental Protection and Water Management and 16 provincial funds. National Fund for Environmental Protection and Water Management co – finances, among other initiatives, implementation of technologies assuring the cleaner production and energy-saving production (Ministry of Environment, 2006).

The important initiative for rising funds for development of clean coal technologies in Poland is creation of the Innovative Silesian Cluster of Clean Coal Technologies in 2005. The target of the Cluster is to build conditions and transfer innovative research solutions around clean coal technologies and their industrial usage. The base of the project is the innovativeness and knowledge transfer concerning clean coal technologies aiming at safer and competitive production and utilization of coal. The operation of Innovative Silesian Cluster of Clean Coal Technologies is based on public-private partnership between science, industry and governments. The Innovative Silesian Cluster of Clean Coal Technologies is an open and unlimited project. The funding members consider adding new partners depending on the purpose of the project (Clean Coal Cluster Information, 2007). The creation of the Cluster is a very important step towards clean coal actions in Poland. European Union representative and at the same time former Prime Minister of Poland is involved in the project. It is very beneficial for Poland in terms of providing financial support in this matter.

Another event which may help to gain the interest of foreign investors and expand financial possibilities is the plan of establishing a Cleaner Coal Center in Warsaw, Poland by GE Energy (Energy Business Review, 2006). This fact will definitely support initiatives associated with clean coal technologies development in Poland and it will be a

clear sign for investors that Poland is an important partner in providing technological improvements in energy sector.

To conclude, efficient clean coal technologies are being explored but need to be further demonstrated. They also require financial resources as well as appropriate changes in the current legislative system to be successfully implemented.

CHAPTER 5 Discussion

The results show that coal will remain for at least next 20 years the dominant fuel in the Polish energy mix (Table 12). It is consistent with the world energy system trend, which according to World Energy Council will continue to be dominated by fossil fuels, making up almost 90% of the total energy supply in 2030 (World Energy Council, 2004).

Table 12 The future role of coal as an energy source in Poland according to coal experts

Answers	Number of people
The role of coal will be very significant	16
The role of coal will depend on prices of other energy sources	4
The role of coal will be significant, but nuclear energy will become our future solution	3

A few survey's participants (4) pointed out that the percentage of coal's contribution to the energy structure in Poland will depend on the prices of other energy sources, mainly the prices of oil. According to International Energy Agency (1997), coal is a competitive fuel in electricity generation, even with oil prices in the region of US\$ 15 to US\$ 18 per barrel. Analyzing the world oil prices in 2007 published by WTRG Economics, it can be observed that the cost per barrel is between 50 US\$ and 78 US\$ per barrel. It gives coal a strong position as a most important fuel in the world and Polish energy mix.

Keeping in mind those facts, Polish hard-coal industry and policy makers have to take into account the future demand for coal and should put special attention on coal production and coal utilization issues.

The challenge for coal is to ensure that it meets all the objectives of sustainable development and, in particular, ensuring that it improves its environmental performance, while continuing to make significant contributions to economic and social development.

As identified in the survey, the main environmental issues facing coal industry in Poland are as follows: greenhouse gas emissions, discharge of saline waters, mine wastes, and ground settling. Those issues can be divided into two groups. First group is associated with coal use and utilization. This group includes greenhouse gas emissions. The second group includes concerns from coal mining activities: discharge of saline waters, mine wastes, and ground settling.

According to Afgan *et al.* (2004), the major long term environmental concern about coal use has changed from acid rain to greenhouse gas emissions – primarily carbon dioxide from combustion. The results of the research are consistent with this observation made by the author. Most of the survey respondents qualified greenhouse gas emissions as a main problem for coal for becoming an energy source in sustainable energy development.

It is however important to mention, that a few interviewees, coal miners, coal communities and associations representatives saw the issues associated directly with coal exploration – saline waters, mine wastes and ground settling among the most important concerns in terms of sustainable coal use in Poland. Those problems were mentioned mainly by people directly affected by coal exploitation in the Silesia region. Respondents emphasized however, that those problems are already being solved.

According to International Energy Agency (1998), the quantities of saline waters was significantly reduced by improved mine management and more selective mining.

Several desalination plants have also been constructed to treat mine water, with further plants planned. The volume of mine waste produced is also being minimized by backstowing where possible and through increased utilization as a construction material (International Energy Agency, 1998).

Seventeen surveyed experts agreed that reduction of greenhouse gas emissions is the key issue when thinking of a coal use in a large scale, taking into account its role in building sustainable resource development. It is however important to mention that greenhouse gas emissions impact on climate change started to be considered as an important problem after Poland joined the EU and this issue is still being researched. A few survey respondents referred me to the literature, published also by them, regarding greenhouse gas emissions from coal use in Poland, their scale and levels. Therefore, despite the fact that survey questions did not cover detailed answers regarding greenhouse gas emissions, for illustrating more clearly this problem in Poland, the main issues from the currently available publications were presented in the result section.

According to all reviewed documents, environmental damage as a result of coal production and use has been severe in Poland. Environmental regulation and policy have been strengthened in recent years. Besides that a system of fees and fines has been introduced to encourage better environmental performance and standards (International Energy Agency, 1998). Poland has signed a number of international agreements aimed at reducing the levels of emissions. At present, even though Poland has adopted all the international agreements, the national strategy on greenhouse emission reductions and climate change policy does not seem to be a priority for the governments. There is a need

for a specific action program to address Kyoto requirements and to build sustainable development in the energy sector.

More changes should be applied in the area of legislative and technological system in order to encourage change in the Polish coal-based energy sector. Currently only two documents and one program within regulatory environment in Poland and EU support initiatives making coal use more environmentally sustainable. Those two documents include Green Paper and VII Framework Program for Research and Technological Development. Among programs only EU Program - Zero Emission Technology Platform promotes technological solutions of coal-based energy development.

According to Piebalgs (2006), the European Commission underlines in the Green Paper that an integrated global approach to climate change is an obligation. The Green Paper does not prescribe the future of specific fuels, but it challenges each of them to prove that they can make an important contribution to sustainable development. This energy source was for the first time considered as a potential contributor to sustainable development. However, to achieve this goal, the coal use sector must go through deep changes in order to achieve lower emissions. The reduction of greenhouse gas emissions is one of the most significant challenges facing the EU energy policy. Individual EU members, including Poland, are unable to effectively prevent the greenhouse effect on their own (Ministry of Economy, 2006). The broad dialogue within European Union, as well as with the rest of the globe on the possible measures to stabilize emission levels over the next decades is necessary. Development and introduction of advanced technological solutions should be one of the issues. The Green Paper strongly emphasises the role for new technologies in improving the state of the environment in terms of

energy resource use. According to Ministry of Economy (2006), for coal this means bringing clean coal technologies as well as carbon dioxide capture and storage to demonstration projects and afterwards to the markets. The opponents of CO₂ sequestration argue that the long-term effects on the environment are unknown; however the potential benefits of this method should give government of Poland “green light” to undertake more research and start demonstration projects to find the possibilities of secure CO₂ storage. Some critics suggest that resources allocated to the clean coal demonstration project should be used to develop renewable sources of energy such as wind and solar. Poland, however, has limited potential for renewable energy development and the use of resources towards clean coal development seems currently more reasonable.

Poland should start the process of applying clean coal combustion technologies and CO₂ capture and sequestration on a commercial scale; However, since wider application of these technologies will bring effects in a distant future, it is necessary to take actions supporting the replacement of the outdated installations in power plants and introduction of new units using supercritical and sub-critical parameters (mainly pulverized and fluidized technologies). Therefore, the decision of regulatory framework creation for coal technology development in Poland should be made. Very good bases for the future Polish actions in this matter are two EU documents: the 7th Framework Program for Research and Technological Development, and the Technology Platform “Zero Emission Fossil Fuel Power Plants”. Besides technological solutions they define the conditions for receiving financial support for the clean coal technologies development.

Interviewed coal experts asked to prioritize target issues for making coal use more environmentally sustainable in Poland generally saw two streams of actions: technological improvements and policy changes. The technological changes were necessary according to most of the respondents. Among policy changes respondents, mainly academicians and coal companies and institutes representatives saw a need to improve coordination within coal mining industry and between coal and energy sector. It can be assumed that increased cooperation between those two sectors could initiate consolidation actions towards more sustainable energy policy instead of currently existing competitions between energy and coal industries. It could bring beneficial legislative changes, development strategies, and financing opportunities moving Polish energy system based on coal towards more environmentally sustainable pathway. It is clear then that only simultaneously initiated consolidation actions and appropriate policy changes could lead to technological improvements in the coal sector. According to International Energy Agency (1997), the introduction of new coal technologies depends not only on market conditions, on the technology cost and technical parameters and energy prices, but also on political issues and public policy.

Polish coal experts identified two ways of technological improvements in coal industry. First, the necessity to develop existing coal-based power plants and second, investing into new clean coal technologies.

The starting point in the Polish case is the process of replacing outdated equipments to produce coal of better quality. Coal preparation is the first and most efficient way of emission reduction during coal burning. The next step is the wider introduction of the advanced clean coal technologies. These technologies bring the

opportunities to increase reductions in the emissions of pollutants and to improve efficiencies.

In the short and medium term the best solutions for Poland is to apply fluidized and pulverized coal-fired combustion technologies using sub- and supercritical parameters. In the long term IGCC technology should be considered which offers promising option for environmentally improved coal use. With high percentage efficiency levels, about 40%, and very high percentage (80-90%) of NO_x and SO_x emissions removal, the further development and deployment of IGCC will have a significant impact on the environment performance of coal (International Energy Agency, 2006). The analysis of the available data on coal gasification showed that for a long term perspective it is also profitable to integrate the production of power, chemicals and other products. According to International Energy Agency (1997), if the potential for integrated power, chemicals and heat production based on coal gasification is realized, it could make a major contribution towards sustainable energy development.

In coal experts' opinion, clean coal technologies development is necessary to build coal into sustainable resource development. They emphasize however, that it is a matter of time. Most of the experts believe that it could happen in the next 10-30 years. Clean coal technologies development can be realized, however many barriers were identified by coal experts. All respondents agreed that financing is the most important barrier in introducing clean coal technologies. According to International Energy Agency (1997), the role of financing institutions is very important in such a capital-intensive industry as coal sector. The financing institutions influence the technology choice and the level of innovation in those choices.

The best knowledge regarding financial support exists among government representatives. About 30% of respondents, mainly from coal associations and companies, said that there is no support, another 10% was not aware of existing co-financing opportunities. It calls for better information flow and promotion strategies regarding existing co-financial sources.

Lack of regulatory framework was another obstacle when introducing clean coal technologies. According to MacRae (1991), ensuring appropriate environmental regulatory framework, providing support for demonstration and research and development programs could significantly help the market in introduction or further development of new technologies.

Also lack of people taking the initiative and decision makers was listed as another barrier. The government and its decision to initiate clean coal technologies development was seen as starting point in thinking about technological change in Poland. According to International Energy Agency (1997), government support for the demonstration projects of clean coal technologies for power generation can be beneficial, because the early market penetration may have to overcome non-commercial barriers. Governments also have an important role in monitoring the research and demonstration projects with some policy measures. Governments can also play an important role in informing the public about the environmental performance of new coal technologies.

According to International Energy Agency (1997), as well as the speakers of the conference attended in Gliwice in 2006, the main players influencing change in coal sector are the coal industry itself, the engineering and equipment supply industries, the electric power utilities, the non-power industrial users of coal, such as the steel and

chemicals industries, and the financing organizations; however large international companies play also very important role. The results of this study is a starting point showing the perspective on clean coal technologies development presented by selected coal industry representatives, coal associations, Polish government, financial institutions, and academia. It is necessary, however, to undertake follow-up research, using larger resources, to ensure that other potentially involved parties are interested in changing the industry and implementing clean coal technologies.

To get a chance to explore the benefits of next generation clean coal technologies in Poland, support from the political side is also required. It is important to create a partnership between coal users and politicians in order to successfully develop clean coal technologies strategies.

As underlined during the conferences and meetings attended during the field work in Poland, also public involvement is very important aspect of the technological change. According to International Energy Agency (1997), general public plays a major role in defining the direction of technological progress. The siting and licensing of coal power plants very often have problems with public acceptability. Furthermore, technological improvements bring increases in the cost of the energy. It is therefore essential, that technology development programs incorporate dialogue and information-sharing with the public in order to obtain its acceptance.

From the results of the survey and after reviewing the existing literature and relevant documents, it can be assumed that with a well-designed policy and legislative system, with the financial support from the EU, it is feasible to develop existing clean coal technologies in Poland, and in the long term the introduction of the next generation

technologies, which are the option for more sustainable coal use in Poland. If coal is to be acceptable as an energy source built into sustainable resource development, it must be produced, transported and used in the ways that protect the environment. At the same time, the cost of complying with environmental requirements must not increase the overall cost of using coal to point that coal becomes uncompetitive in the market.

CHAPTER 6 Summary, Conclusions, Recommendations

6.1 Summary

Hard-coal is the main source of energy in Poland. Poland is among the world's leading producers and consumers of hard-coal. The forecast regarding coal demand in Poland for the next 20 years shows that coal will play very significant role in the energy structure in Poland. This situation may increase coal's impact on the environment. The environmental impacts include those of the mining industry and electricity generation. The most difficult problem of the coal use remains still high emission of SO₂, NO_x, and CO₂.

Due to its large negative impact on the environment, coal is not often considered as a part of the sustainable energy development. Therefore, activities with regard to limiting the impact of the coal sector on the environment and building environmentally sustainable energy system based on coal became the main interest of the conducted research. The objectives of the study were: 1) to identify the main environmental impacts of coal as an energy source in Poland; 2) to describe existing Polish laws and related EU laws and regulations aimed at ensuring coal use is sustainable; 3) to establish target issues for making coal use more environmentally sustainable; and 4) to examine how technological or other improvements can contribute to improving the environmental sustainability of target issues.

The above objectives were addressed using the following methods: extensive review of the literature, interviews with energy experts in Poland, and field observations and attending energy-related meetings and conferences.

The research focused on the collection of both historical as well as current data. Outcomes of the data analysis were summarized, synthesized and included in the final report.

The report concluded that in order to achieve emissions reductions and to increase coal's contribution to environmentally sustainable energy use in Poland, it is necessary to apply advanced clean coal technologies and provide appropriate legislative and policy changes.

6.2 Conclusions

Coal is a key energy source in Poland and according to the forecasts will remain the main energy source for at least the next 20 years. The main environmental concern of the energy structure based on coal is high greenhouse gas emissions. Poland has already undertaken first steps to reduce the emissions; however the Kyoto Protocol requirements and the strict European Union emissions standards require more changes in the energy sector. Changing current energy system in Poland will need time, because there is interdependency between measures taken in favor of emission reduction, the necessity to change a fuel mix and social-economic issues (employment reductions in the mining sector, possible energy security disruptions). Currently the most reasonable option for Poland is to find the ways to make the energy system based on coal more environmentally sustainable.

However, in order to map out Poland's route towards sustainable energy development, based mainly on coal, it is necessary to formulate changes in the current legislative system of Poland and EU. For coal production and consumption in Poland to be more sustainable, it is necessary to make appropriate technological changes.

Therefore, the advantage should be taken of the clean coal technologies which give the opportunity to meet the standards of environmental protection.

There are three main technological solutions minimizing coal's impact on the environment. First of all, coal preparation can to some extent remove impurities from coal. Second, there are ways to increase coal based energy efficiency and reduce coal use. The last solution is clean coal technologies which are directly oriented to minimize the impact of greenhouse gases on the environment. The clean coal technologies applicable for Poland include both cleaner and more efficient technologies for coal combustion, including fluidized and pulverized technologies using supercritical and subcritical parameters, in the long term perspective IGCC technology, as well as carbon dioxide capture and storage.

The coal based energy system should be examined within the sustainability context. Energy policy changes, paying more attention to more efficient and effective technologies should be initiated to start considering coal-based energy structure in Poland in a sustainable perspective. Without legislative solutions promoting coal as a cleaner energy source, changes in this sector, associated with improving coal's environmental performance, would be much more difficult to realize.

6.3 Recommendations

The following recommendations can be drawn:

1. To undertake deep research regarding applicability and feasibility of developing clean coal technologies in Poland;

Close coordination between academicians, central, local and regional governments, as well as mining and energy companies is essential to undertake deep research in the field of clean coal technologies. It should become the common goal for all the parties, because

it would minimize the impact of coal on the environment, and at the same time it would encourage and attract investors to the region, what would help to reduce the rate of unemployment.

The development of clean coal technologies should be done in a consortium of manufacturers, operators and research institutes. Due to the technical and economic risks, public aid as well as government policy support are necessary.

Because technological improvements result in the increase in the energy prices, public support is needed to start or continue any research and development initiatives.

2. To provide changes and amendments in Polish and EU laws and regulations, which will enhance development and demonstration projects of clean coal technologies (for example: tax incentives for companies that will decide to implement CCT);

As far as one of the most important concerns for Poland and EU remains greenhouse gas emissions, the authorities should undertake the steps to encourage investments in clean coal technologies. One of the solutions could be changes in the tax regulations allowing companies that will decide to implement CCT to apply for a tax rebate. However to make such a change it is necessary to start public discussion about this issue and undertake more research to prove the effectiveness of those technologies.

3. To develop clean coal technology roadmap as a starting point for the future clean coal technology policy;

Ministry of Economy with the cooperation of the Ministry of Environment should make a decision regarding creating clean coal technology roadmap for Poland. It would show interest in developing the technologies on the highest governmental stage and on the other hand, government involvement would be a clear indication for investors,

researchers etc. that they may expect governmental support in case of developing CCT projects.

4. To undertake follow-up research using survey with the engineering and equipment supply industries, the electric power utilities, the non-power industrial users of coal, such as the steel and chemicals industries to ensure their interest in developing clean coal technologies in Poland.

Before making the final decision on implementing clean coal technology development, Ministry of Economy should research the market and demonstrate the interest of all potentially involved parties.

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Appendices

Appendix 1

Research Questions for Survey

1. What are the main environmental concerns regarding coal extraction and processing in Poland?
2. What should be the target issues for making coal use more environmentally sustainable?
3. Which technological or other improvements can contribute to improving the environmental sustainability of coal use in Poland?
4. Does the current regulatory environment in Poland and EU associated with the environmental impacts of coal support initiatives making coal use more environmentally sustainable?
5. Is there any public support for stimulating development in mining technology, coal preparation and coal conversion, as well as research and demonstration projects in coal combustion and gasification in Poland?
6. What are the perspectives for introducing clean coal technologies in Poland?
7. Are there any research and demonstration projects associated with introducing clean coal technologies already in place?
8. What are the main barriers against introducing clean coal technologies in Poland?
9. What are the main environmental issues which should be addressed in creating new hard-coal restructuring policy?
10. What would be the future place of coal in maintaining sustainable energy development in Poland?

Appendix 2

Results of the survey

SURVEY QUESTION	EXPERTS' ANSWERS
1. What are the main environmental concerns regarding coal extraction and processing in Poland?	<p>Greenhouse gas emissions</p> <p>Waste and waste disposal</p> <p>Saline waters</p> <p>Dust pollution</p> <p>Ground settling</p>
2. What should be the target issues for making coal use more environmentally sustainable?	<p>Introducing clean coal technologies</p> <p>Solving the problem of methane</p> <p>Removing sulfur from coal</p> <p>Improving efficiency</p> <p>Providing energy security</p> <p>Improving coordination in coal mining Industry</p> <p>Reclamation of dumps</p> <p>Improvement of safety in coal mines</p>
3. Which technological or other improvements can contribute to improving the environmental sustainability of coal use in Poland?	<p>To improve the quality of combustion</p> <p>CO₂ sequestration</p> <p>To introduce gasification (IGCC) powderized and fluidal technologies (supercritical and ultra-supercritical parameters)</p> <p>To increase the role of clean coal with low contamination of sulfur</p> <p>Combustion of coal together with biomass</p> <p>To improve quality of coal</p> <p>To maintain stability of the system</p> <p>To allow wider vertical consolidation in coal industry</p> <p>To increase cooperation between energy and hard-coal sectors</p> <p>To introduce energetic willows</p> <p>To increase the level of individual</p>

SURVEY QUESTION	EXPERTS' ANSWERS
	<p>customers</p> <p>To open Poland for imported coal</p>
<p>4. Does the current regulatory environment in Poland and EU associated with the environmental impacts of coal support initiatives making coal use more environmentally sustainable?</p>	<p>Lack – only Green Paper</p> <p>Research and Development – National Sectoral Plan of Development</p> <p>No – support in favor of renewable resources</p> <p>Zero Emission Technology Platform – EU Program</p>
<p>5. Is there any public support for stimulating development in mining technology, coal preparation and coal conversion, as well as research and demonstration projects in coal combustion and gasification in Poland?</p>	<p>Clean Coal Cluster</p> <p>The National Fund for Environmental Protection and Water Management</p> <p>VI Framework Program of the European Community for research, technological development</p> <p>Research Fund for Coal and Steel</p> <p>No public support in place</p> <p>Lack of data</p>
<p>6. What are the perspectives for introducing clean coal technologies in Poland?</p>	<p>It is necessity (Kyoto)</p> <p>No other way to develop coal industry</p> <p>There are chances, but in 10 years</p> <p>Clean coal technologies and nuclear energy will be developed at the same time</p> <p>There is no possibility</p>
<p>7. Are there any research and demonstration projects associated with introducing clean coal technologies already in place?</p>	<p>CO₂ sequestration has just started (small scale)</p> <p>Clean Coal Cluster (Program UE and Polish Government)</p> <p>Institute for Chemical Processing of Coal – research</p> <p>Biomass + coal</p>

SURVEY QUESTION	EXPERTS' ANSWERS
8. What are the main barriers inhibiting introducing clean coal technologies in Poland?	Finance Lack of people taking the initiative No interest in clean coal Lack of adequate law system – acts and regulations Lack of skilled workers Lack of decision makers Interests of particular sectors Psychological Barriers Political beliefs Organizational and technical Technological problems Lack of consortium NGO's Bad perception of coal Social cost
9. What are the main environmental issues which should be addressed in creating new hard-coal restructuring policy?	Introducing clean coal technologies Introducing gasification Solving the problem of methane Put more attention into coal + biomass Improving coordination in coal mining industry
10. What would be the future place of coal in maintaining sustainable energy development in Poland?	Will still remain very significant Coal will remain significant, but nuclear energy will be our future The role will depend on prices of other energy sources

Appendix 3

Permission for using the data



MINISTRY OF ECONOMY

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December 6, 2007

Ministry of Economy authorizes Magdalena Mateuszczyk, graduate student at the University of Manitoba, Winnipeg, Canada to use in her forthcoming Master's thesis "An Assessment of Coal's Contribution to Sustainable Energy Development in Poland" the data included in the following documents:

1. Ministry of Economy, Labour and Social Policy (2004). Restructuring of the Hard Coal Mining Sector during the Period 2004-2006 and Strategy for the Period 2007 – 2010. Warsaw: Poland. Government Printing Office;
2. Ministry of Economy and Labour (2005). Energy Policy of Poland until 2025. Warsaw: Poland. Government Printing Office;
3. Ministry of Economy (2006). The Standpoint of the Government of the Republic of Poland on the Green Paper: A European Strategy for Sustainable, Competitive and Secure Energy; and
4. Institute for Chemical Processing of Coal (2006). Coal Gasification – the Solution for its Effective Utilization. Document prepared for the Ministry of Economy, Warsaw, Poland.

Deputy Director

WICEKZ
TAMENTU

Aleksandra
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Aleksandra Magaczewska

Appendix 4

Informed Consent Letter



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Research Project Title: The Assessment of Coal's Contribution to Environmentally Sustainable Energy Development in Poland.

Researcher: Magdalena Mateuszczuk

I am currently in the process of conducting my Masters Thesis research. The purpose of this study is to identify the ways which can make coal use in Poland more environmentally sustainable. It has already been approved by the Joint-Faculty Research Ethics Board at the University of Manitoba (Canada).

This consent letter, a copy of which will be left with you for your records and reference, is part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like know more details about something mentioned here, or information not included here, please feel free to ask for clarification. Please take the time to read this carefully and to understand any accompanying information.

In the course of the research you will be asked a series of questions that will help me to assess if coal use in Poland can make contribution to sustainable energy development and what are the ways to make coal use in Poland more environmentally sustainable. You will be asked to participate in a survey session that will last in between 30 minutes and 1 hour. If more time is required, a subsequent meeting can be arranged at your convenience. This survey may be conducted at your place of work, home, or at another location of your preference.

Your responses to questions will be documented in a notebook. However, your names will not be recorded with the responses to ensure that your identity remains confidential unless you indicate that I may use your name or want to be acknowledged by name. Your names will be recorded in a separate notebook for organizational purposes; for example, in case you need to be contacted for further information or clarification at a later date. Towards the end of the research process there will be presentation of the interpretations of the data gathered. You will have an option to disagree to any such information, in which case, the information would be suitably modified with your inputs. The data

provided by you will be used to complete a progress reports, my Master's thesis, and may be potentially published in an academic journal.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

If you have any complaints or further questions about the project, your concerns may be directed to the Human Ethics Secretariat at the University of Manitoba (204-474-7122), margaret_bowman@umanitoba.ca, or to my advisors, Thomas Henley, Professor or John Sinclair, Professor who may be contacted at 204-474-8373, henley@ms.umanitoba.ca and jsincla@ms.umanitoba.ca. Please be advised that the staff at these offices speak only English.

Participant's Signature

Date

Researcher's Signature

Date