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Clean coal technologies for silesia region – results Of regional foresight

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ABSTRACT

The present paper deals with the results of the foresight analysis concerning the development of energy technologies in Upper Silesia. Twelve experts representing science, industry and independent authorities were involved in these investigations. Upper Silesia is a specific region in Poland, characterized by coal energy technologies. As 9 result of STEEP and SWOT analyses several scenarios of energy technology development have been elaborated. In the course of the voting of experts two scenarios (innovative and moderate development) have been selected. Both of them stress the need of developing clean coal technologies in Upper Silesia. The final results of regional foresight are road maps of the energy technologies development in Upper Silesia.

Keywords

Foresight, clean coal technologies

1.Introduction

In Poland nearly 95% of electricity is generated by the combustion of coal (61% – hard coal, 34% – lignite). In the case of Upper Silesia this proportion is still higher, approaching 100% of hard coal. As far as CHPs are concerned the share of coal amounts to 84 % all over the country, and in Upper Silesia this share is higher. Thus, the specifics of Poland, particularly of Upper Silesia, indicates the leading role of energy coal technologies both at present and in the future. Among other fossil fuels which may be considered, only natural gas can be taken into account, mainly because of its ecological properties, but its price and the possibilities of political blackmail belong to its drawbacks. The development of clean coal technologies reduces the ecological distance to the natural gas. Therefore the application of natural gas in Polish electroenergy and district heating systems is rather limited. The localization of traditional nuclear power plants is in Upper Silesia nearly impossible due to the lack of water. Merely the nuclear-coal synergy with the application of nuclear high-temperature reactors may be considered. The possibilities of producing electricity from renewable energy are in Poland rather poor and in Upper Silesia lower than in other parts of Poland, except biomass.

The only applicable option for Upper Silesia are clean coal technologies. The arguments prevailing in the case of the new power unit Łagisza are actual for the whole of Upper Silesia (a lower risk of discontinuity of the supply and price of hard coal in comparison with natural gas). Also European and worldwide arguments support energy coal technologies. Based on coal presently 39% of electricity are generated and by 2030 an increase of up to 45% is predicted. The availability of coal all over the world is assessed to last for 200–300 years, whereas the availability of natural gas and crude oil only for 40-60 years. Moreover, the price of coal is credible for a

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longer time thanks to the regular distribution of resources of all over the world.

In the near future (up to 2020) supercritical and ultrasupercritical PF and CFB power units will be applied. Later on IGCC aiming at polygeneration must be taken into consideration. Clean coal technologies are a bridge to their transformation into technologies with nearly zero emission technologies connected with oxy-fuel combustion and CO2 capture and storage installations [1,2,3,4,5,6,7,8].

The most effective way of heat and electricity production is the application of CHPs as suggested in the EU directive concerning the promotion of cogeneration. With the existing demand for heat the potential of cogeneration is nowadays not utilized sufficiently in Poland, not even in Upper Silesia. This concerns also the adaptation of power units to heat production. Upper Silesian power plants are located in the neighborhood of large towns, being therefore competitive resources of heat for district heating. The economical efficiency of CHPs can be improved by the application of thermal storage. Another way of increasing their energy and economical efficiency is the introduction of the so-called “trigeneration” i.e. the connections of CHP with cooling systems.

2. Energy policy of Poland and EU

The project “Energy policy of Poland up to 2030” stresses the fact that coal will still be the crucial element of energy security of the country [9]. Coal should also become an element of increasing the energy security for the whole Europe.

In the Green Paper of March 8, 2006, called “European Strategy for Sustainable, Competitive and Secure Energy” it has been stressed that energy security is one of the fundamentals of our daily life. This Green Paper forms the basis of a new complexive European energy policy, as the individual energy policies of 27 countries are at present not sufficient [10].

In March 2007 the document “Energy Policy for Europe”, shortly called “Energy Package 3x20%”, was issued stressing the security of energy supply as the first aim of the EU energy policy. The dependence of EU on the supply of primary energy amounts at present to 50%. If the effectiveness of the utilization of energy is not improved and the share of our own resources of primary energy is not increased this dependence may even grow to 70–80% in the year 2030.

First of all the Energy Package 20x30% requires that by 2020 EU should reduce the emission of CO2 by at least 20% in comparison to 1990. This will be connected with the introduction of expensive installations of CO2 sequestration and a decrease of the efficiency of power units fired with fossil fuels.

It has also been proposed to attain by 2020 a 20% share of renewable energy in the total energy consumption and at least 10% biofuels in transport. The next aim is to increase the effectiveness of the primary energy consumption by 20% up to 2020.

3. Analyses steep and swot-crucial factors and crucial technologies

The aim of the analysis STEEP (Social, Technological, Ecological, Economical and Political factors) of the environment was to determine those factors characterising the external environment which in the opinion of experts influence the development of the energy technology in Upper Silesia.

The results of the analysis SWOT (Strengths, Weaknesses, Opportunities, and Threats) comprise the following crucial factors:

- extensive fuel-energy industry,
- consolidating trends in the fuel-energy sector,
- technological retardations in the energy sector,
- low potential of capital expenditure in the fuel-energy industry,
- lack of a coherent strategy for the mining and energy industry,
- lack of programmes concerning the technological restructurisation of the energy sectors,
- incentive for external investors,
- new energy policy of the EU stimulating the development of clean coal technologies,
- attainment of the leadership in the innovation of the energy sector,
- stable strategy of the development of the fuel-energy sector in Poland,
- activation of privatization in the energy sector,

- international competition on the energy market,
- lack of support by the government for demonstrative projects concerning the energy sector,
- lack of cooperation between science and industry in the range of modern coal energy technologies,
- necessity of CO_2 sequestration.
- The successive ranking suggested by experts in the list of crucial technologies is as follows:
- PF power units; supercritical parameters (Power Stations 600),
- PF power units;ultrasupercriticalparameters,
- PF power units; supercritical and ultrasupercritical parameters; CO_2 capture,
- PF oxy-fuel combustion technology,
- pressurized combustion of coal and combined with GT technology,
- CFB power units; supercritical parameters,
- pressurized fluidized-bed power units; supercritical parameters,
- fluidized power units with external DeSOx and DeNOx installations; supercritical parameters; oxy-fuel combustion,
- combined gas and steam power plants; steam cooling of the blades,
- multi-fuel power units; supercritical parameters; CO_2 sequestration,
- IGCC and CO_2 capture,
- coal and nuclear synergy,
- CHP units with CFB,
- thermal storage in CHP units,
- heating boilers fired with methane from coal mines,
- production of heat from renewable sources and by the co-combustion of wastes,
- polygeneration based on clean coal technologies,
- fuel cells and microturbines,
- Building Cooling Heating and Power,
- deep cleaning of coal,
- territorial systems of waste energy recovery,
- fuels from wastes,
- underground coal gasification.

4.Variants in the reaction of the environment

Innovative variant

It is to be assumed that the economy of Poland will be characterized by a stable strategy of the development of the fuel-energy sector, the support of its consolidation and programms backing demonstrative projects. This might consolidate the leadership of the Silesian energy industry by making up for the so-far tardy progress. Simultaneously the EU energy policy will stimulate the development of clean coal technologies. Foreign investments will compensate the low local potential of investments in Upper Silesia. Then this region will have the chance of reaching the leading position in clean coal technologies.

The variant of moderate development

The energy policy of Poland will favour the consolidation of energy industry, ensure the conformability of the strategy of the mining and energy industries and a stable development of the fuel-energy sector. Technological retardation will be made up only to some extent. The government will support demonstrative projects only restrainedly. Investors from outside this region will only partly compensate the deficiency of Upper Silesian's own capital. Considerable investments will be of a spectacular character. The EU energy policy will stimulate the development of clean coal technologies only reluctantly. The strong fuel-energy industry of the region will retain its position in the country. It will be difficult, however, to attain the leading position in the domain of clean coal technologies.

Stagnation variant

The energy policy of Poland does not favour the development of the coal energy sector. Technological retardations cannot be made up in this sector. The region will have to depend on its own capital. The EU energy policy will be conservative in relation to clean coal technologies. Demonstrative projects will not be supported. The fuel-energy industry may encounter problems with retaining its leadership in Poland. The regional energy industry will lose its ability to compete on the European energy market. Energy investments will have the character of running reconstructive ventures – new power units will not be constructed.

Recession variant

The energy policy of Poland does not favour a stable development of the fuel-energy sector. There will be no consolidation of the energy sector, and demonstrative projects will not be supported. Technological retardations will grow. External investors will not be interested in investments in the fuel-energy sector of Upper Silesia. The technical state of productive installations will systematically deteriorate. Privatization in the energy sector will be stopped. The European Union will lose its interest in the development of clean coal technologies. The regional fuel-energy industry will lose its leadership in the country and its competitiveness on the European market.

5. Prevision of energy technology development

Traditional coal energy technology

PF and CFB power units. Supercritical parameters on the level of "Power Stations 600". Centralized district heating. CHPs based on fluidal techniques. Peak load gas turbines and boilers.

Near zero-emission coal energy technology

PF and CFB power units based on oxy-fuel combustion. Ultra supercritical parameters. Centralized district heating basing on CHP fluidized units. Distributed system of heat supply based on low-emission coal and renewable energy sources.

IGCC systems

Oriented on polygeneration. Coal and nuclear synergy. Industrial energy systems utilizing technological fuel gases. Centralized district heating systems based on CHPs fired with coal.

Multifuel energy systems

Power and CHP units fired with coal, gas and biomass. District heating systems co-fired with wastes in CHPs. Utilization of waste energy in district heating systems.

Low-carbon development of energy systems

Gas and combined gas-steam units. Utilization of industrial waste energy. Fuel from wastes. Utilization of renewable energy sources and wastes in district heating systems.

The matrix of the prevision of the technological development is presented in Table 1. In order to choose the proper scenarios of the technological development a matrix has been created connecting the previsions with the variants of the reaction of the environment. This matrix has been subjected to the opinion of experts, whose goal was to determine the feasibility (probability of realization) of the respective previsions in the accepted variants of the reaction of the environment. The results of the experts voting were averaged and presented in Table 2.

6. Scenarios of energy technology development and road maps of energy technology in upper Silesia

Based on the analysis of the matrix connecting the previsions with the variants of the reaction of the environment the following scenarios of technological development have been specified.

Innovative scenario with two leading previsions:

◦ near zero-emission coal energy technology Based on PF and fluidal techniques,
◦ near zero-emission coal energy technology Based on IGCC.

Scenario of the moderate development with two leading previsions:

◦ traditional coal energy technology oriented towards the so-called "Power Stations 600",
◦ multifuel energy systems.

Specification of the innovative scenario

The economical policy of Poland favours an intensive development of the fuel-energy sector. The support of a vertical consolidation of the electroenergy systems will strengthen the position of the Polish energy group on the European competitive market. The EU energy policy will simulate the development of clean coal technologies. As a result demonstrative projects concerning CCT will be supported by the Polish government. Making up for technological retardations this will strengthen the leadership of the Upper Silesian fuel-energy industry. External capital will flow in compensating the low investment potential of the Upper Silesian region. Besides the modern electroenergy system the high-efficiency cogeneration technology will be developed ensuring an effective supply of heat. Installations of thermal storage will improve the economical effectiveness thanks to the relocation of electricity production during the day. CHPs will be connected with cooling systems, the so called "trigeneration technologies". Centralized district heating systems will be based mainly on CHPs with fluidal boilers resulting from positive experiences with CFB boilers gathered so far.

Distributed heat supply systems will be based on low-emission coal, natural gas and renewable energy sources. Industrial CHPs will be modernized by installing combined gas and team units fired with technological fuel gases.

Specification of the scenario of moderate development

It is to be assumed that the energy policy in Poland will not restrict the vertical consolidation of the electroenergy system, but develop a stable strategy of the coal-energy sector. Considerable investments in the energy sector will be spectacular. Thus, the technological retardation will be only partially made up. The support of the government concerning demonstrative projects will be restricted. In spite of that the coal-energy industry will keep its strong position. The EU will only reluctantly stimulate the development of clean coal technologies, so that the leadership of Upper Silesia in this domain will be hampered.

The electroenergy sector will be oriented towards the application of PF and CFB technologies belonging to "Power Stations 600". Coal technology will be joint with gas and biomass technologies into multifuel technologies, the positive feature of which is its fuel flexibility.

Centralized district heating will be developed towards CHPs Based mainly on CFB boilers meeting the criterion of high-efficient cogeneration. The potential of high-efficient cogeneration will be increased thanks to the reconstruction of already existing boiler houses into CHPs.

Thermal storage will be installed in CHPs in order to improve the economical effectiveness thanks to the increased peak production of electricity. In centralized district heating wastes will be fired or co-fired. The utilization of industrial waste energy is foreseen in so-called "territorial systems of waste energy recovery".

In peak installations respective GT and gas boilers will be applied in electroenergy and district heating systems. The road maps of the development of energy technologies in Upper Silesia presented in Tables 3 and 4 correspond to two scenarios of technological development selected by the voting of experts.

7. Summary

In the perspective of the next 20 years no spectacular changes are to be expected in the structure of primary energy carriers used for the production of electricity and heat. The importance of coal is essential, particularly in Poland. Natural gas plays a worldwide, besides coal, also an important role in the production of electricity and heat. New energy technologies are developing in various ways. None of them may be neglected due to processes, the development of which is difficult to be predicted, including changes of the climate. All these options are the bases of sustainable development.

As far as natural gas is concerned the perspectives are not at all as optimistic as ten years ago [11] and due to the rather high price of natural gas in Poland it will not be competitive if compared with power units fired with coal. This does not exclude the application of natural gas at the peak load of the Polish electroenergy system. Therefore, coal will still be in Poland the fundamental primary fuel used for the production of electricity and heat. According to the opinion of European experts after the year 2020 the importance of coal will increase.

The final results of this foresight there are two scenarios of the technology development of the energy economy in Upper Silesia up to 2020. The most probable scenarios are the innovative scenario and the scenario of moderate development. The pessimistic scenarios of stagnation and recession have been rejected because against the background of the EU, of which Poland is a member country, seem to be improbable.

The choice of two scenarios, viz. the optimistic and realistic one, does not mean a sharp division between them. The realization of the innovative (optimistic) scenario is conditioned by the expected turn of the EU energy policy in favour of clean coal technologies. The moderate (realistic) scenario does not predict such an optimistic turn. The development of power units up to the year 2020 will be based on the technology "Power Station 600". Multifuel technologies and the technology of waste energy recovery will be further developed.

Both these scenarios do not exclude a situation in which up to 2020 both of them will be partially realized. Neither are investments in IGCC technology aiming at polygeneration excluded. Both scenarios assumed a development of highly efficient cogeneration complying with the EU Directive 2004/8/EC. Underground gasification of coal and nuclear-coal synergy are forecast for the years after 2020. The commercial level of oxy-fuel combustion is also predicted to be achieved after 2020.

PF technology with supercritical parameters has proved after twenty years experience on nearly 400 units all over the world that the reliability of such units is at least as high as that of power units with subcritical parameters. As reference parameters nowadays 28,5 MPa and 600/620°C may be assumed at a net efficiency of 46 %. The boundary parameters of steam corresponding to the latest achievements of material engineering may be assumed as 30 MPa and 630/630°C. The future of PF power units after 2015 depends on the implementation of the project AD 700.

Power units with fluidized techniques ensured first of all the possibility of attaining low SO_2 and NO_x emissions. Another advantage of this technology is the fuel flexibility. The future of these units up to 2030 consists in the growth of the power rating of the units and supercritical parameters.

Because of fuel flexibility the multifuel technology is an interesting option thanks to the its independence of the market conditions on the worldwide fuel market. Multifuel power units might be competitive with the PF technology if their following additional advantages are used:

◦ combustion of large amounts of biomass in a special boiler,

◦ clutching in the gas part in the peak load of the electroenergy system.

The nowadays operating IGCC units cannot compete with the supercritical PF technology and CFB because they have not achieved yet a comparable reliability, whereas the capital investments are higher. These relations may vary if obligatory CO2 sequestration is introduced.

The promotion of highly efficient cogeneration systems is a priority for EU involving potential advantages connected with savings of primary energy and a reduction of harmful emissions, particularly CO_2. This may contribute to an increase of the security of energy supply and competitiveness of EU.

The technology of CO_2 reduction has not been so far the crucial problem of power units, but coal energy units must distinctly reduce the emission of CO_2. At the present state of CO_2 sequestration techniques the co-combustion of biomass and the increase of efficiency are so far the only way in Poland to reduce CO_2 emissions in energy coal technologies. The increase of efficiency from 33 % to 46 % has made it possible to reduce the CO2 emission in Polish thermal power stations by 28 %.

According to the opinion of experts it seems to be more rational to take this fact into account instead of neglecting the increasing share of CO2 in the atmosphere. The trend towards achieving a high efficiency, of the power units, the decrease of own consumption and losses of transporting electricity is the most rational way of saving primary energy and reducing the emission of CO2.

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Table 1. Matrix of the previsions of the energy technology development

Crucial technology		Prevision of energy technology development				
No	**Name**	**Prevision 1**	**Prevision 2**	**Prevision 3**	**Prevision 4**	**Prevision 5**
1	PF power units; supercritical parameters (Power stations 600)	x				
2	PF power units; ultrasupercritical parameters (36 MPa, 700/720oC/720oC).		x			
3	PF power units; supercritical and ultrasupercritical parameters; CO2 capture		x			
4	PF oxy-fuel combustion technology		x			
5	Pressurized combustion of coal and combined with GT technology					x
6	CFB power units; supercritical parameters	x				
7	Pressurized fluidized bed power units; supercritical parameters		x			
8	Fluidized power units with external DeSOx and DeNOx installations; supercritical parameters; oxy-fuel combustion		x			
9	Combined gas and steam power plants; steam cooling of blades					x
10	Multi-fuel power units; supercritical parameters; CO2 sequestration		x		x	
11	IGCC and CO2 capture			x		
12	Coal and nuclear synergy			x		
13	CHPs units with CFB	x	x	x		
14	Thermal storage in CHP units	x	x	x	x	x
15	Heating boilers fired with methane from coal mines				x	x
16	Production of heat from renewable sources and co-combustion of wastes				x	x
17	Polygeneration based on clean coal technologies			x		
18	Fuel cells and microturbines		x			x
19	Building cooling heating and power		x			x
20	Deep cleaning of coal	x	x			
21	Territorial systems of waste energy recovery				x	x
22	Fuels form wastes				x	x
23	Underground coal gasification			x		

Table 2. Matrix of combining the previsions with the variants of environment behaviour

Variants of environment behaviour	Probability of prevision implementation (range 1- 5)				
	Prevision 1	**Prevision 2**	**Prevision 3**	**Prevision 4**	**Prevision 5**
Innovative	4.00	4.50	4.50	4.00	3.50
Moderate development	4.38	3.50	3.75	4.13	3.38
Stagnation	3.63	2.13	2.00	3.38	3.00
Recession	3.13	1.25	1.25	3.38	2.63

Table 3. Road map of the innovative scenario

Technologies		Time horizon														
No	Name	before 2008	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	after 2020
1	PF power units; ultrasupercritical parameters (36 MPa, 700/720oC/720oC).											●	→	→	→	→
2	PF power units; supercritical and ultrasupercritical parameters; CO2 capture														●	→
3	PF oxy-fuel combustion technology															●
4	Pressurized fluidized bed power units; supercritical parameters															●
5	Fluidized power units with external DeSOx and DeNOx installations; supercritical parameters; oxy-fuel combustion															●
6	Multi-fuel power units; supercritical parameters; CO2 sequestration														●	→
7	IGCC and CO2 capture													●	→	→
8	Coal and nuclear synergy															●
9	CHPs units with CFB	●	→	→	→	→	→	→	→	→	→	→	→	→	→	→
10	Thermal storage in CHP units				●	→	→	→	→	→	→	→	→	→	→	→
11	Polygeneration based on clean coal technologies						●	→	→	→	→	→	→	→	→	→
12	Fuel cells and microturbines									●	→	→	→	→	→	→
13	Building cooling heating and power				●	→	→	→	→	→	→	→	→	→	→	→
14	Deep cleaning of coal														●	→
15	Underground coal gasification															●

●→ **commercial implementation**

Table 4. Road map of the scenario of moderate development

Technologies		Time horizon														
No	Name	before 2008	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	after 2020
1	PF power units; supercritical parameters (Power stations 600)				●	→	→	→	→	→	→	→	→	→	→	→
2	CFB power units; supercritical parameters		●	→	→	→	→	→	→	→	→	→	→	→	→	→
3	Multi-fuel power units; supercritical parameters; CO2 sequestration															●
4	CHPs units with CFB	●	→	→	→	→	→	→	→	→	→	→	→	→	→	→
5	Thermal storage in CHP units				●	→	→	→	→	→	→	→	→	→	→	→
6	Heating boilers fired with methane from coal mines	●	→	→	→	→	→	→	→	→	→	→	→	→	→	→
7	Production of heat from renewable sources and co-combustion of wastes				●	→	→	→	→	→	→	→	→	→	→	→
8	Deep cleaning of coal															●
9	Territorial systems of waste energy recovery			●	→	→	→	→	→	→	→	→	→	→	→	→
10	Fuels form wastes				●	→	→	→	→	→	→	→	→	→	→	→

●→ **commercial implementation**