Utilization of Colliery Gas from Coal Mines, Poland: A Combined „PHARE" & „DEPA" Project

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ABSTRACT

The project originated in 1997/1998 and was aimed at delivery to Poland of five colliery gas driven gensets for cogeneration. The plants were intended to be installed at five Polish coal mines located in the Upper Silesian Coal Basin (USCB). The hardware (gensets) delivery part was co-financed from the PHARE fund, with a ca. 50%-high financial participation of the Polish beneficiaries, while the major tasks related to the logistic and technical support for the entire project were financed by the Danish Environmental Protection Agency (DEPA), from the Danish Governmental program DANCEE, oriented at environmental assistance to the countries of Central and Eastern Europe. In Poland the PHARE part was administrated by the Polish National Fund for Environmental Protection and Water Management, Warsaw. As the final result, two gensets have been installed and put into operation in two coal mines in which they use colliery gas as a fuel, while the destination of the three next gensets has been moved within this PHARE project into the Geothermal Plant in Zakopane, that is a mountain spa resort in the south of Poland. Now these gensets operate fuelled with natural grid gas. Upon completing the PHARE component connected to delivery and installation of the five gensets, the remaining project component financed from DEPA (DANCEE) has still been continued in order to define and support further project implementation opportunities in USCB, for state-of-the-art utilizing of colliery gas. Based on cooperation with the Polish Coal Companies and with municipalities in the USCB region, several next project opportunities have been defined and subjected to technical and economic evaluating within the DEPA component. As the result, several Environmental Impact Assessments and Feasibility Studies as well as a Business Plan have been made for the Polish beneficiaries. These documents evaluate emerging opportunities for more efficient utilization of CMM. The analyzed options include next cogeneration plants and a PSA plant for gas upgrading and sale to the Polish National grid. These projects may additionally contribute to the traditionally good CMM utilization system in USCB. All analyzed and evaluated CMM utilization options give promising economic indices and good environmental effects deriving from further mitigation of GHG emission. If all the proposed options were implemented, the additional total yearly emission mitigation would reach ca. 106 thousand (metric) Tons of Carbon Equivalent, with the project objects lifetime reaching at least ten years each. Realistic environmental results depend on actual implementation of the project proposals. Owing to their promising environmental effects and good economy, at least two of the options proposed within the DEPA component became subject to interest of both Polish and Danish governmental environmental agencies, as potential opportunities for emission trading.

1. INTRODUCTION

The Polish hard coal mining industry has a long tradition in utilizing of coal mine methane because the problem of using this gas has always been present in the Polish mining sector. In the past time, the Polish mining sector has had implemented pioneer achievements and solutions in this field, applied a long time before the issue of colliery gas utilization has become considered more important all over the world. A good example is the historical (carried out about 50 years ago) undertaking of methane recovery through surface wells from the so called *Marklowice Field* and use of the recovered gas for a couple of years as a local energy carrier in the municipality.
Another example can be the fact, that beginning 60's/70's, for many years, the colliery gas drained from the mines belonging to the today's *Jastrzebie Coal Company S.A.* , was collected into a ring-pipe system constructed solely for this purpose. The colliery gas was compressed and transmitted to heavy industry plants in the town Gliwice, over a distance of ca. 60 km. Part of this ring-pipe system is operating till now, however in a changed configuration and only for local purposes.

2. BACKGROUND OF THE DEPA (DANCEE) / PHARE PROJECT

For the recent few years also some ecologically oriented foreign institutions became interested in efficient and state-of-the-art utilization of colliery gas in the region of Silesia, Poland. This gas is in fact a by-product from coal mining. This interest is coupled among others with the opportunity of future common participating in the worldwide system of emission trading, focused on mitigating of greenhouse gases emission down to the reference level of the early 90's of the past Century.
This resulted in numerous projects, carried out also in Poland, like the pilot project financed by the European Union assistance program named PHARE (project marked PL 9507.01.01), owing to which in two Polish Silesian coal mines two generating sets driven by IC engines fuelled with colliery gas have been installed. Capacity of each of these cogeneration units is 543 kW_{el} plus 703 kW_{th}. In total, in the Polish mines five machines of this kind are operating, however they have various capacities. Two of these machines have been acquired owing to a PHARE grant gained by Poland. The units generate power and useful heat based upon colliery gas drained from the coal mines. The total rating efficiency of each unit exceeds 83%, actually reaching 87%.
Beside such international institution like PHARE, the subject has also risen interest of the Danish Environmental Protection Agency (DEPA), which through its assistance program DANCEE (Danish Cooperation for Environment in Eastern Europe) has supported implementation of the above mentioned PHARE project. In addition to this, the DEPA project, described in this paper, has supported several advanced economic and environmental studies aimed at implementing in the region of Silesia of the next, state-of-the-art plants for utilizing of colliery gas. The special interest was put on the local energy related benefits deriving from these project proposals. One of the important targets was to include local municipalities among the project Beneficiaries.

For the first moment it might be a bit surprising that this was Denmark who shown its interest in colliery gas in Poland, as there are no coal mines neither problems of this kind in Denmark. However, for many years, basically from the great oil crisis in the early 70's, the Danish companies and institutions have worked out a significant experience in the field of energy efficiency and they are still very interested in this subject. No matter, whether the issue is biomass, biogas, wind energy etc., or 'normal' ways of efficient utilization of the already generated conventional energy - the questions of energy efficiency as well the issues of correct utilization of alternative fuels or waste energy, are in Denmark still taken into consideration very seriously, almost traditionally. In case of colliery gas an additional aspect focuses the Danish interest: to mitigate methane emission as a greenhouse gas.

State-of-the-art methods of efficient utilization of coal mine methane and any investments in this field are strongly capital intensive, what can create investment obstacles to the Poland's mining sector, for quite obvious reasons. This is why the opportunity of involving financial means deriving from the international environmental programs ratified by Poland in the area of CO_2 emission trading, seems to be particularly interesting. In the technical sense there are still many things to be done, because the methane reserves in the Polish hard coal deposits are vast, as well in the currently mined coal seams as in the gobs.

3. SCOPE OF THE PROJECT

The project contained two components. The first one was technical assistance (TA) to support the PHARE component, including import and installation of five gas driven gensets intended to use colliery gas. Finally, as a result of project modification, three of the genset units have been installed in a boiler plant fuelled with natural grid gas in an alternate location of Zakopane mountain resort. Two engines have been installed and put into operation in two coal mines belonging to the former *Ruda Coal Company S.A.*

The second project component included several studies aimed at economic and environmental assessment of next implementation opportunities in few alternate locations in which utilization and use of colliery gas will result in significant environmental and economic benefits. The studies included Feasibility Studies, Business Plan and Environmental Impact Assessments for the plants proposed for installing in the near future. Within these studies some technical and economic solutions have been proposed and discussed with the Beneficiaries, in relation to the future plants layout. This aspect has been subject to optimization within the DEPA project component, in terms of economy and environmental effects.

Within the project several investments have been analysed in terms of environmental benefits and in terms of economic feasibility. All sub-projects contributing to the overall scope of work can be divided into three groups, depending on their status at the end of the reported project.

These groups are as follows:

1. Implemented projects:
   - CHP plants at former *Ruda Coal Company S.A.*,
   - CHP at *PEC Geotermia Podhalanska S.A.*,
2. Project under investment decision:
   - PSA plant at *Jastrzebie Coal Company S.A.*,
3. Proposed potential further implementations:
   - CHP plant at *Marcel* - Marklowice site,
   - CHP plant at *Rydultowy HOB Plant* site.

The diagram below shows schematic of locations of the implemented projects and proposed next plants covered by the PHARE and DEPA / DANCEE project components.

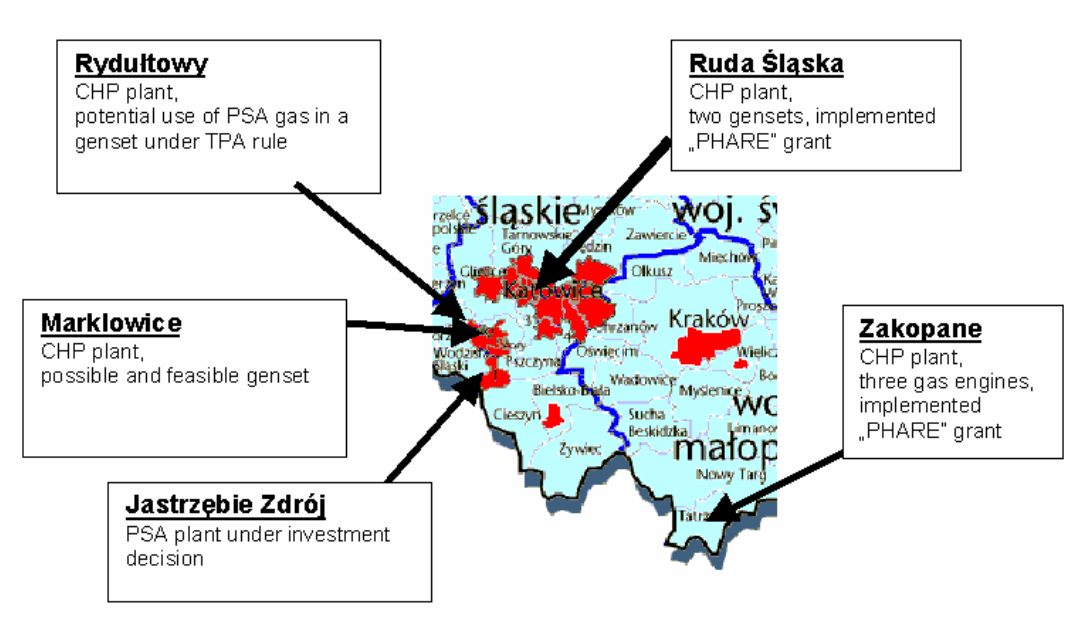

Figure: Locations of the project sites subjected to the PHARE and DEPA project components

4. IMPLEMENTATIONS

RUDA COAL COMPANY (REGION OF SILESIA)

The PHARE component of the subject project has included two major contracts on delivery, assembling and start-up of five gas engine driven generating sets. Finally two sets of this kind have been installed at the coal mines belonging to the former *Ruda Coal Company S.A*. One machine has started to work at the *Bielszowice* mine and the other one at the *Halemba* mine.

Both engines are of the same size and capacity. These are *Jenbacher* units (made in Austria), having 543 kW of power and 703 kW of heat, each. Both units are fuelled with colliery gas. Composition of the colliery gas streams is slightly different in both mines, so that staring-up of the engines required separate setting them up and also required special work in terms of adjusting the controls and parameters.
One of the most important conclusions of this experience was that it was necessary to carefully prepare the colliery gas injected into the engine. This preparation process required careful removal of fine particles and humidity, upstream the engine inlet system. This was because the presence of these contaminants resulted in blocking the fine fuel filters placed in the gas-train inlet to the engines. This problem caused some difficulties, because usually colliery gas is moved away from the mine headings by means of water-circulation vacuum pumps, so that it is saturated with humidity at the pressure outlet from the drainage system. It also contains some suspended particles having so fine size, that it is impossible to move them away completely. It the system's 'bottle-neck', such as fine inlet gas filters, the micro-fines collect during operation time in the filter pores making it necessary to either regenerate or replace the filters relatively often.
On the other end of the generation unit, the AC generator requires relatively stable parameters of the electrical grid, to which it is interconnected on its power supply side. The automation system is sensitive to rapid drops in voltage in the local power grid.

Once the technical problems have been solved, the equipment started to operate correctly, giving good economic results. As the PHARE contractual conditions required input from the Beneficiary's side, the total value of the plant was twice as high as the PHARE grant. The grant included the engines themselves along with their start-up, while the own input of the Beneficiary included site preparation and all installations. Taking this into account it can be stated, that owing to avoided costs of purchasing power from the grid and on-site generation of useful heat in other facilities, the payback time of the investment money spent by the Beneficiary shall not be longer than 3 years.
Contribution from DEPA Project included technical assistance (TA) to the Beneficiary and to the Contracting Authority (Polish National Fund for Environmental Protection and Water Management) and its value was not included in the economic calculations.

Environmental effects include mitigation of GHG emission and some other emission mitigation that results from coal-to-gas conversion to generate equivalent amount of power and heat otherwise produced in coal fuelled facilities.

The on-site measurements related to environmental issues, made by an independent company, have fully confirmed accordance of the actual emissions with the assumptions set in the contract. Also the engines efficiency has been confirmed. The actual, measured efficiency achieved during the first period of operation reached 87%.

GEOTERMIA PODHALANSKA, ZAKOPANE (TATRA MOUNTAINS)

The Beneficiary company *PEC Geotermia Podhalanska S.A.* has been selected by the Contracting Authority, that means by the Polish National Fund for Environmental Protection and Water Management, Warsaw, upon withdrawal from the project of the *Rybnik Coal Company S.A.*, who was the initial Beneficiary of the PHARE Project. In that way three gas gensets previously intended to be put into operation on three sites belonging to the mentioned coal company, have been moved to *PEC Geotermia Podhalanska S.A.* in the mountain resort of Zakopane and adopted for fuelling with pipeline quality natural gas supplied from the National gas grid.
In that way the set of three engines and power generators, of the same type as in Ruda (*Jenbacher*, 543 kW_{el} and 703 $kW_{thermal}$) have started to work for base-load heat demand of the sub-regional district heating system developed all along the Podhale Valley, counting some 25 km length, between the towns of Zakopane and Nowy Targ, with many small villages around and in between. The engines have been installed in the local boiler plant in Zakopane, as a part of a complicated heating system that includes (and is still under development) geothermal heat system, gas fuelled peak-load boilers system, heat pumps and the three gensets granted by PHARE .
The entire heating system in Podhale Valley has a very good design in terms of energy efficiency. The three PHARE granted gensets provide heat for baseload demand in Zakopane and power for deep-well injection pumps used to inject geothermal water back to the rock strata, after extracting its useful heat. The whole system is also equipped with heat pumps and other facilities that improve its thermal efficiency.
Even though the three engines granted by PHARE became only a small part of the entire geothermal system in the sub-region of Podhale, they contribute to the very high technical standard of this system. It should be mentioned in this place, that – regardless of the job made in the DEPA project by *KAMPSAX-COWI A/S* - an important role in the system designing was carried by another Danish company *Houe & Olsen*.

Environmental effects obtained by use of the gensets are smaller than if they were fuelled with colliery gas, however some effects can still be defined. They result from coal to gas conversion for generating of equivalent amount of energy in an alternative remote power plant either heat in local boiler stations fuelled with coal. It is important to underline in this place, that Zakopane is a famous Polish holiday resort, open all around a year, and its surroundings are a health resort, so that any activities that contribute to improvement of air quality are very desired in that area. This very complicated and expensive energy project including utilization of geothermal energy is aimed at significant improvement of air quality in the region, and the use of the small set of the three gensets perfectly fits to this purpose.

The obtained mitigation in emission of airborne pollutants is of big importance to the Zakopane town which is the capitol of a famous Polish tourism and recreation area.

5. FURTHER ACTIVITIES AND PROJECTIONS

PSA PLANT AT JASTRZEBIE COAL COMPANY (SILESIA)

The PSA project idea and primary activities have been initiated by the *Jastrzebie Coal Company S.A*. The objective of the project was to build and operate a PSA plant in order to upgrade the colliery gas that remains not used from the existing colliery gas utilization system at the *Pniowek* coal mine, that incorporates two large gensets, a peak-load bi-fuel coal/methane boiler and other use of colliery gas for technology. The surplus gas presently drained and the next colliery gas additionally available through intensification of gas drainage at the *Pniowek* mine will become inlet gas stream into the projected PSA plant. The DEPA project in this respect was aimed at providing Feasibility Study, Business Plan and Environmental Impact Assessment for a PSA plant. One of the objectives of the DEPA component was to define optimized options of project financing, sale of product gas and involvement of international emission trading programs to support the PSA project implementation and operation. The planned capacity of the PSA plant will reach 15-17 million standard cubic meters of methane per year, in the form of pipeline quality gas injected to the National natural gas grid. Because the proportions and relationships between investment and operational costs / prices that refer to the PSA project are proportionally and respectively similar in the USA and in Poland, the total economic effects expected from the project implementation are also similar. For the project calculated as for only own capital invested (model line) with total sale of upgraded gas at a price that could be somehow competitive against the present Polish tariff price, over ten years of the pre-assumed plant lifetime, IRR reaches 16-18%. Such results have also been presented in earlier publications by American authors in relation to PSA plants operating under the US conditions. Correct financial engineering, careful use of investment loan, and - first of all - additional incomes to be available from emission trading programs, could improve the project economy or could lead to competitive reduction of the price for upgraded gas. In that respect direct sale to the grid either use of the Third Part Access (TPA) rule could have been taken into consideration. However, under the existing gas tariff pricing relationships in Poland, the direct application of the TPA rule does not give sufficiently promising results from the viewpoint of potential remote purchasers of upgraded gas. This situation results from the obvious price related conflict of interest between the gas producer and gas user. Another aspect is a relatively high gas transmission fee defined in the gas pricing Tariff. Finally, direct sale to the National gas grid occurred to be the best option. However, there still exists a hypothetical / potential opportunity to make a TPA contract between the PSA plant operator in Jastrzebie and *Geotermia Podhalanska S.A.,* that might close the 'logical loop' of the PHARE / DEPA project concerning the idea of using coal mine methane. Whatever, the crucial point for the project economics is availability of financial means from international CO_2 trading, that could result from the Kyoto Protocol provisions and consecutive international documents. Within the DEPA component of the project, relevant documents have been prepared by *KAMPSAX-COWI A/S* and submitted to the respective authorities. These documents are aimed at launching the CO_2 emission trading system between Poland and Denmark.

MARKLOWICE – *MARCEL* MINE CHP AND RYDULTOWY CHP

These two sub-projects within the DEPA component are smaller parts of the reported project. Especially interesting however, is the opportunity of enhanced use of colliery gas at the *Marcel-Marklowice* coal mine / municipality site. The DEPA project documentation included here a feasibility study of optimized use of available coal mine methane in a way to co-generate energy with significant mutual benefits to the *Marcel-Marklowice* coal mine and to the local municipality of Marklowice (5 thousand inhabitants). The idea of this project, initiated by local authorities, is also aimed at strong social benefits to the municipality inhabitants and visitors. This is among others an optimized heat delivery system to the municipal buildings and a project of a recreation center with heated swimming pools, all supplied from the CMM fuelled CHP.

SUMMARY OF THE PHARE / DEPA PROJECT OUTCOMES

Specification	Approximated Budgeted Sum		Beneficiary	Subject
	US$	US$		
PHARE Component	700 000		Ruda Coal Company	2 operating genset plants
Beneficiary's Contribution		600 000	Ruda Coal Company	2 sites, installation
PHARE Component	1 050 000		Geotermia Podhalanska	3 gensets
Beneficiary's Contribution		450 000	Geotermia Podhalanska	1 site, installation
Total Investments	**1 750 000**	**1 005 000**		**5 operating CHP Plants**
DEPA/DANCEE Component	**580 000**			
		TA to the PHARE Project component	Ruda Coal Company	Technical Assistance for PHARE and project EIA
			Geotermia Podhalanska	Technical Assistance for PHARE and project EIA
		Continuation of the DEPA component	Jastrzebie Coal Company	Feasibility, EIA *) and Business Plan, PSA plant
			Marcel Mine & Marklowice municipality	Feasibility and EIA *), CHP plant
			Rydultowy Heating Plant	Feasibility for CHP plant
Total, DEPA Component	**580 000**			**Studies, EIA's*) and Business Plans**

*) - EIA = Environmental Impact Assessment

SUMMARY OF THE POSSIBLE ENVIRONMENTAL EFFECTS

	Project site	From reducing CMM			CO_2 mitigation from replacing equivalent hard coal		Total TCE reduction	Other pollutants mitigation from replacing equivalent hard coal				
		CH_4	Equival CO_2	Equival TCE	Addit CO_2	Addit. TCE		SO_2	NO_x	particulates	B-a-P	Tar substances
		Tons per year			Tons per year		T/year	Kilograms per year				
1	Ruda Coal Company SA	1673	35133	9586	9749	2660	12246	88191	30657	23333	0,069	181
	Geotermia Podhalanska	0	0	0	14000	3820	3820	144539	20165	38448	0,113	186
2	PSA plant, Jastrzebie CC	12062	253310	69117	0	0	69117	0	0	0	0	0
3	Marcel mine-Marklowice	1532	32172	8778	13098	3574	12352	165358	57479	43888	0,129	212
	Rydultowy HOB plant	0	0	0	31308	8543	8543	187821	55839	60915	0,003	609
	TOTAL POSSIBLE EFFECT	**15267**	**320615**	**87482**	**68155**	**18597**	**106079**	585909	164140	166584	0,314	1188

1 – Implemented plants, **2**- Under implementation, **3**- Potential follow-up