

Can Synthetic Fuels Help Alleviate Europe's Petroleum Dependence?

AN OVERVIEW OF COAL-TO-LIQUIDS IN POLAND

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Energy Charter Secretariat*



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FOREWORD

The oil sector today is going through some fundamental changes: national oil companies now control the bulk of production, with international petroleum companies more often playing a secondary role in making decisions on production, investment and markets; prices are at their highest and are more volatile than ever before. The resulting security of supply concerns are especially important in the transport sector, which almost exclusively uses liquid fuels made from crude oil and is particularly vulnerable to sharp variations in supply and prices of refined products. The rapidly growing energy demand requires major continuous investments in all fields of the energy sector, including the supply of liquid fuels.

Such changes result in investors and governments facing new types of risk and challenges. In order to best address these, the Energy Charter opened a Risk Reduction Dialogue in 2004, aimed at political and regulatory risk for foreign investors, in line with the investment-protection focus of the Energy Charter Treaty.

In 2007, the Energy Charter produced a publication "Driving without Petroleum? A Comparative Guide to Biofuels, Gas-to-liquids and Coal-to-liquids as Fuels for Transportation." The current paper looks at certain aspects of the coal-to-liquids (CTL) market in greater detail. Based on case study data developed by Poland, the report provides background information on CTL technologies, policies and regulations, and highlights some basic technology, economic, and investment risk factors associated with coal-to-liquids projects in Europe.

This paper was prepared by Mr. Michal Kozak of the Hertie School of Governance in Berlin during his internship at the Secretariat.

The delegation of the Republic of Poland provided special expertise to the Energy Charter Investment Group during its October 2007 Meeting. Mr. Marek Sciazko, Director of the Institute for Coal Processing in Poland, made a special contribution highlighting the review undertaken by the Polish Ministry of Economy in 2006 regarding production of liquid fuels from hard coal and the associated barriers and opportunities. It was underlined that the official government programmes for mining and power generation industries in Poland refer to CTL as a development option.

The main findings of this report include the fact that a coal-to-liquids plant in Poland would be capital-intensive, as the minimum required scale of coal conversion is approximately 6 million tons per year. On the other hand, modern CTL technologies offer a relatively good yield of diesel fuel. Accordingly, coal-based liquid fuels can be competitive in comparison with those obtained from crude oil at current market prices. In addition, co-generation of electricity and co-production of methanol make CTL plants economically efficient without special incentive measures. The main risks are related to regulatory issues, e.g., coal-to-liquids plants are currently categorised as chemical plants, and different CO₂ regulations apply to the energy and chemical industries.

This report is made publicly available under my authority as Secretary General of the Energy Charter Secretariat.



André Mernier
Secretary General
11 February 2008

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Summary

Coal-to-liquids (CTL) is a well-known technology that allows the production of liquid fuels from coal. Though there is only one case of commercial-scale application (by Sasol in South Africa), recent increases in oil prices and security concerns have spurred renewed interest in liquefaction technologies among coal-rich countries.

Main challenges for the CTL technology are:

- High investment costs;
- Uncertainty of long-term oil prices;
- Environmental concerns, particularly CO₂ emissions.

These uncertainties have prompted some governments to give support or plan to provide incentives for the development of a synthetic fuels industry. These may range from loan guarantees via tax credits to import controls and guaranteed production take-off. Providing that the currently pending CTL-friendly legal framework will be accepted in the USA and that China will complete its ambitious programme of constructing CTL plants, the CTL industry may experience an unprecedented growth. Although there are serious environmental concerns regarding large carbon dioxide emissions, technological solutions are available (carbon capture and sequestration).

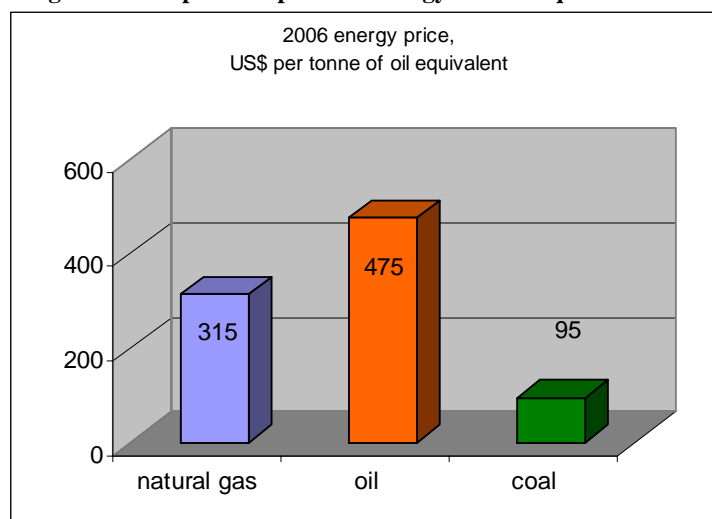
Poland is heavily dependent on import oil and gas supplies, therefore using large reserves of domestic coal to provide liquid fuels (CTL) or synthetic natural gas (SNG) is justified from energy security point of view. However, an enterprise has to be economically sound, provide reasonable return on high investment costs (around \$5 billion), and offset market uncertainty. Therefore there is a need of a detailed study to assess the feasibility of the CTL industry in Poland. At the same time, close monitoring of international developments and adequate funding for research is indispensable. To provide a balance between profit-orientated and security considerations, engagement of Polish state-owned coal, oil and gas companies and Government support to establish this industry may be warranted.

1. Introduction

a Why search for alternative liquid fuels?

Very high and volatile crude oil and natural gas prices together with growing concerns about energy security provide a strong stimulus to search for alternative sources of energy (see Figure 1). This is especially valid for petroleum-based liquid fuels used in transportation, as oil covers 35 % of global energy consumption and provides 96% energy used on transportation.¹ Even increased efficiency of cars or use of bio-fuels is unlikely to compensate for the constant growth of demand for transportation fuels. Other options for transport fuel (LPG, CNG) do not seem to find widespread application. An option could be liquefaction technology, which has made significant progress, allowing for higher efficiency and less environmental pollution. Main options are: Coal-to-liquids (CTL), gas-to-liquids (GTL) and biomass-to-liquids (BTL). Taking into account low prices and availability of coal, the chemical coal processing becomes an attractive alternative.

Figure 1: Comparative prices of energy on heat equivalent basis



Source: BP Statistical Review of World Energy June 2007

b) What is coal-to-liquids technology?

The technology of converting coal into liquid fuels goes back into the beginnings of the 20th century, with the Bergius method for direct liquefaction and the Fischer-Tropsch method for indirect liquefaction. Nevertheless, due to high costs and low oil prices, liquefaction found very limited application under stressful circumstances (Germany during WW II, the Republic of South Africa at the time of apartheid). Temporary revival of interest in coal liquefaction came with the 1973 oil crisis, followed by R&D projects developed in Australia, Germany, Japan, the UK and the USA. However, stabilisation of oil prices froze the research and it took some 30 years and another oil crisis to return to CTL technology as an alternative source of liquid fuels.

¹ "Coal: Liquid Fuels", World Coal Institute, 2006.

Coal is a solid with hydrogen to carbon (H/C) molar ratio of 0.8. This H/C ratio is between 1.3-1.9 for crude oil and around 2 for gasoline and diesel fuel. To convert coal into liquid fuels, it is necessary to introduce the lacking hydrogen into its structure, which can be done either by pyrolysis or – more efficiently – by direct or indirect liquefaction.²

There are several different methods of coal liquefaction. The applied technology and the type of coal used have a considerable impact on yield, characteristics and mixture of products. During the process pollutants of coal such as sulphur and nitrogen are largely eliminated and produced hydrocarbons are refined in a way similar to distillation of crude oil. Final products are clean liquid fuels (gasoline, diesel, jet fuel) and other chemical compounds (naphtha, lubricants, sulphur, ammonia).

Indirect liquefaction is a commercially proven technology, currently used by Sasol. During the first stage of processing, coal is gasified with steam to produce syngas (a mixture of hydrogen and carbon monoxide). After removing sulphur compounds and particles the syngas is reacted over a catalyst at a relatively low pressure and temperature. Final products depend on the type of reaction and on the catalyst. Indirect liquefaction is characterised by ultra clean fuels and is well suited for CCS, though the process is less efficient (around 40% of overall energy efficiency) and produces less calorific fuel.

Direct liquefaction is a potentially more effective way (overall energy efficiency is in the range of 60-70%), and it has been chosen for the Chinese Shenhua project. There are a couple of different variations of technologies, yet the main features of the process are the dissolution of coal in a hydrogen-rich solvent at high temperature and pressure and further hydrocracking with a catalyst. Apart from higher efficiency, this method allows adjusting for the type of product necessary and produces fuels of high energy density. Obtained oil products require refining before going to the market. Drawbacks of this method are higher operating costs and higher CO₂ emissions.

A **hybrid concept** combines the advantages and limits the disadvantages of the above mentioned methods, yet with higher costs. Another looming alternative may be a patent-pending method developed by Global Resource Corporation, USA. The process uses specific frequencies of microwaves to obtain petroleum products from various hydrocarbons. This process is expected to lower costs and limit CO₂ emissions, yet it still has to be proven in large-scale applications. In principle, synthetic fuels can also be produced together with electricity in advanced IGCC plants (integrated gasification combined cycle). This process is known as **polygeneration**.

The liquefaction process is characterised by high process water demand³ and higher CO₂ intensity compared to refinery oil processing. Carbon dioxide is considered a greenhouse gas and is subject to an emission trading scheme in the European Union. However, the CCS technology (carbon capture and sequestration) offers a potential to control emissions and

² J. Świądrowski, A. Rejman-Burzyńska, E. Jędrzyk, "Bezpośrednie upłynnianie węgla jako perspektywa otrzymywania paliw ciekłych w Polsce", *Chemicz*, N0 6, Vol. LX (2007), p. 304.

³ Between one and two cubic meters per tonne of DAF coal (dry ash basis).

even use the CO₂ commercially⁴ (for instance for enhanced oil or gas recovery or for a chemical industry).

Main companies which have advanced technologies of coal liquefaction are: Chevron, General Electric, Lurgi, ExxonMobil, Sasol, and Shell.

The viability of a CTL enterprise is very much dependent on oil prices. Therefore the main question is whether the “trigger price” has been reached for bring competitive synfuels on the market, compensating for high investment costs and market uncertainty.

c) Characteristics of the coal market

Coal as an energy source has many advantages: It is cheap, reliable and distributed more evenly than oil and gas around the world, with vast resources in OECD countries. Furthermore, by application of advanced clean technologies it can get rid of the stigma of dirty fuel.

The bulk of the total world coal output (4,050 MT) is used for power generation. In the last 20 years global coal production increased by 40% (with projections to reach 7,000 MT in 2030) and showed biggest growth in Asia. Largest coal producers are China, the USA, India, Australia and South Africa. Due to high transportation costs most of production is consumed domestically, with only 18% sold on international markets.⁵

European coal mining has witnessed a constant downsizing of production and currently EU imports 50% of its hard coal consumption (180 of 360 MT). Poland supplies roughly half of EU's hard coal and Germany half of lignite production. Environmental considerations and increasing extraction prices lead to downsizing of coal production.⁶

Table 1: Proved reserves of coal at the end of 2006 (hard coal and lignite), in million tons

	Coal proved reserves	% of world reserves	Reserves to production ratio*
USA	246,643	27.1	234
Russia	157,010	17.3	>500
China	114,500	12.6	49
Australia	78,500	8.6	210
South Africa	48,750	5.4	190
Ukraine	34,153	3.8	424
Poland	14,000	1.5	90

Source: BP Statistical Review of World Energy June 2007

* R/P – reserves to production ratio, indicates number of years that coal may be extracted at the current production rate.

⁴ “SPECIAL REPORT: Fischer-Tropsch oil-from-coal promising as transport fuel”, Oil & Gas Journal, February 26, 2007.

⁵ “The coal resource. A comprehensive overview of coal”, World Coal Institute, p. 13-15.

⁶ Germany, for instance, has decided to withdraw state help and thus phase out hard coal production till 2018.

2. Regulatory Framework and Debate over the Coal-to-liquids Industry

Although so far the only commercially proved installation is operated in the Republic of South Africa, China has also started development of CTL industry. A number of other countries carry out research, develop pilot CTL plants or consider implementation of this technology (Australia, Germany, Indonesia, Japan, Philippines, Ukraine, and the United States).

a) In the Republic of South Africa (RSA) the general legal framework for liquid fuels has special regulations pertaining to synfuels.

The RSA flagship company Sasol, world-class leader in synfuels technology, continuously shows very good economic standing and profitability. It converts coal to oil and chemicals at a capacity of 150,000 bbl/d and meets 23% of domestic demand for petroleum products. The other producer of synthetic fuels is PetroSA, which converts natural gas into liquids (45,000 bbl/d). The synfuels industry contributes considerably to RSA's economy by investment, provision of jobs, taxes and by savings on foreign exchange. Providing (directly and indirectly) employment to 170,000 people, Sasol is responsible for 2% of RSA employment and generates around 4% of its GDP.⁷

Though both Sasol and PetroSA are private companies, they originated as government-backed initiatives and as means to reduce the country's energy dependence; they wouldn't have developed without generous governmental support. The following measures and regulations helped to establish the synfuel industry:

- *Refinery investment incentives, capital investment costs covered from public funds* (a special levy imposed on motorists).
- *Imports controls*: All domestically manufactured products had to be absorbed by the market before imports were allowed.
- *Guaranteed off-take of synfuels*: At times up to 30% of domestic fuel production from crude oil had to be mothballed due to market oversupply (partially compensated via the synlevy funded by motorists).
- *Guaranteed market access* and competition controls.
- *Administratively determined petroleum products prices*, based on import parity price and domestic factors. Synfuels manufacturers sell at the administered price without reference to their production costs.
- *Tariff protection*: The reference fuel price has been framed between \$23 and \$28. If prices fell below the floor price, synfuels producers were compensated from the Equalisation Fund, funded by a special levy on petroleum products. Excessive economic rent resulting from high oil prices was taxed at a special rate (25%) and pooled in the same fund (so the profits did not flow to the state treasury).
- *Development of fuel infrastructure* and distribution networks was skewed to meet the needs of domestic manufacturers.

⁷ R. Miszkiel, "Sasol – zgazyfikowanie węgla", Rurociagi Nr 1/42/2006.

The synfuels industry brought considerable benefits to the country's economy. Nevertheless, questions for opportunity costs do arise. Moreover, there are serious concerns that the present dispensation *system benefits producers and shareholders of synfuels disproportionately at the expense of citizens and taxpayers*. A special report on possible regulation reform gives an interesting insight and potentially valuable experience of managing the regulatory regime.⁸

b) The USA depends extensively on imported liquid fuels and in 2007 alone spent some \$250 billion on oil imports. Since the U.S. possesses large coal reserves and advanced technologies, it has a potential to become a significant producer of synthetic fuels.

So far, The Energy Policy Act (EPA, 1992) has constituted the general framework facilitating the use of alternative fuels. The renewed version from 2005 offered further financial incentives, loans and loan guarantees. Moreover, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU, 2005) provides 0.5 \$/gallon excise tax credit for CTL products. However, this regulation expires in 2009, before any significant investment on CTL can be introduced.

The biggest quest to support coal-derived liquid fuels is the Coal to Liquids Fuel Promotion Act of 2007, introduced to the Congress. This act modifies the Energy Policy Act of 2005 and calls for the following actions:

1. *To secure loan guarantees for first ten large-scale CTL facilities* (min. 10,000 bbl/d), providing a programme for matching loans.
2. *To extend 20% Investment Tax Credit* to the first ten CTL plants (capping the credit at \$200 M). Also extension of the \$0.5 per gallon tax credit till 2020 and provision of incentives for application of CCS technology are requested.
3. *To integrate the CTL fuels into the military supply chain*, by providing the U.S. Department of Defense⁹ with funding to purchase and test synthetic fuels. Also application of multi-year contracts and using synfuels as Strategic Petroleum Reserve is proposed.¹⁰

The fate of these amendments is still pending and should find its resolution till the end of 2007. Such framework could greatly support activities in a dozen of states, which have passed CTL legislation, introduced incentives, or even engaged in CTL projects.¹¹

Nevertheless, these amendments find also a strong resistance. The main criticism of this amendment is that it is going to provide generous subsidies to coal mining companies and develop "dirty" coal fuels industry, contributing substantially to carbon dioxide emissions.

⁸ "Possible reforms to the fiscal regime applicable to windfall profits in South Africa's liquid fuel energy sector, with particular reference to the synthetic fuel industry", report prepared by a task team appointed by the Minister of Finance of RSA, 9th February 2007.

⁹ DOD alone consumes 400,000 bbl/d. In comparison, Poland's consumption is 450,000 bbl/d.

¹⁰ Introduction of senator Bunning of Coal-to-liquids Promotion Act of 2007, <http://www.futurecoalfuels.org/documents/010507_bunning_introduction.pdf>.

¹¹ Incentives include: tax credits, financing assistance, grants, alternative fuels incentives, alternative energy portfolio standards, public vehicle fuel mandates, site assistance, accelerated permitting, tax increment financing, property tax relief, alternative energy revolving loans. Moreover, some cities require fleets to use alternative fuels. More: R. Bezdek, "Policy implications for CTL in the USA", in: "Coal-to-liquids. An alternative oil supply?" CIAB Workshop Report, IEA, November 2006.

c) China started developing its CTL technologies in the late 1980s and after 1993, when the country became a net oil importer, the project was given strategic importance.

The Shenhua Group took lead in the process and has began developing its large project in Ordos, Inner Mongolia (est. costs \$3 billion, ultimate output 5 million bbl/y). Soon after, two other major coal producers followed the example; the Lu'an Group in Tunliu, Shanxi Province (a modest 160,000 T/y) and the Yankuang Group in Yulin, Shaanxi Province (total investment of \$12.5 billion, resulting in an estimated output of 10 M tons of oil products by 2020). The Chinese CTL projects break even at an oil price of \$25 per barrel and some insiders expect that up to 50 MT per year of coal-derived liquid fuels could be produced by 2020.

Though other provinces, lured by prospects of considerable gains, followed suit and there are about 30 CTL projects at the stage of detailed planning or feasibility study, only these three initial projects won approval of the National Development and Reform Commission (NDRC, the national industrial watchdog). Regulations have been issued to ban local undertakings under 3 M bbl/y and without viable technology before main projects have been finished. Restrictions should not apply to foreign companies; Royal Dutch Shell and Sasol have engaged in projects which, if they go ahead, could bring onstream some 150,000 bbl/d CTL capacity by 2012, at a cost of more than \$10 billion.

Except for the high capital intensity and standard investment risks, these large-scale projects may involve considerable environmental risks. CTL processes consume large quantities of water, which is a challenge for the rich in coal but poor in water north-western regions of China. Additionally, without the necessary treatment facilities, waste gas, waste water and industrial effluents would be a significant burden to the environment. Furthermore, increased consumption of coal would lead to faster depletion of this resource, which at current level of production is estimated to be available for only 50 years.¹² These considerations, coupled with reliance on commercially unproved technologies, has resulted in speculations about the possible revision of the Chinese liquefaction programme.¹³

d) The EU. Although coal liquefaction technology originated in Europe, currently there is no CTL industry in EU countries.

There is also limited interest in engaging in this technology, due to the intended phasing-out of coal production and also to serious environmental concerns, especially with respect to CO₂ emissions. Emissions of carbon dioxide are a serious challenge for synthetic fuels. Though currently chemical processing of coal is not subject to CO₂ emissions restrictions, it is likely that this approach would be changed.

e) Poland, due to its large coal resources, is a country where CTL technology has perspectives for development.

¹² "Govt aims to rein in growth of coal liquefaction", Xinhua Net, 10 August 2006, <http://news3.xinhuanet.com/english/2006-08/26/content_5008489.htm>; "China reins in fast growth of coal-to-liquid fuel projects", Xinhua Net, 29 July 2006, <http://news.xinhuanet.com/english/2006-07/29/content_4890665.htm>.

¹³ "China may halt production of liquefied coal", China Daily, 10 June 2007, <http://www.chinadaily.com.cn/china/2007-06/10/content_890875.htm>.

The “*Strategy for coal mining industry in Poland 2007-2015*” acknowledges the importance of the Polish coal mining industry and foresees significant investment in this sector. It also calls for an earnest assessment of synthetic gas and liquid fuels production possibilities. The government is supposed to promote the application of CTL technology and the Ministry of Economics should coordinate the debate concerning synthetic fuels as well as initiate the development of a feasibility study. Nevertheless, any liquefaction plant in Poland should be a business enterprise.

Policy incentives would have significant impact on the development of CTL in Poland. The main options are:

- Loan guarantees;
- Investment tax credit;
- Subsidies for synfuels via reduced excise tax.

Loan guarantees influence significantly the cost of a project, as it allows to finance a greater part of the project through debt and at the same time lowers the debt interest rate. A favourable change in the debt/equity ratio could allow domestic companies, which otherwise might find serious difficulties in raising such funds, to engage in a CTL project. The associated risk is huge, as in case of failure of the enterprise the government would have to cover debts. However, the Treasury would not lose tax revenue from granting subsidies. The situation is exactly the opposite in the case of reduction of excise tax: The risk of launching the enterprise is on the investor whereas the government would lose tax revenue when the project succeeds. Investment tax credit is supposed to have relatively modest impact on the enterprise.¹⁴

¹⁴ Compare: “Baseline Technical and Economic Assessment of a Commercial Scale Fischer-Tropsch Liquids Facility”, DOE/NETL-2007/1260, April 9, 2007, p. 55-58.

3. Coal-to-liquids: The Case of Poland

a) Polish energy security: Could CTL be the right solution?

Poland has some special considerations with respect to its energy security: Only 35% of its energy needs are covered by imports, whereas this ratio is 50-70% for other EU countries. This might rank Poland as the country with highest level of energy security among the 27 EU members; however this is largely because 90% of power generation comes from domestic coal.

The situation looks different with reference to other energy sources. Annually Poland consumes 21.3 MT of oil and 15 billion m³ of natural gas, covering with imports 90% and 65% of its consumption respectively.¹⁵ Energy resources come mostly from the former Soviet Union and are supplied via Russian pipeline networks. In this way Russia, the main Polish supplier, has a significant control over import transportation routes.

Coal to Synthetic Natural Gas (SNG)

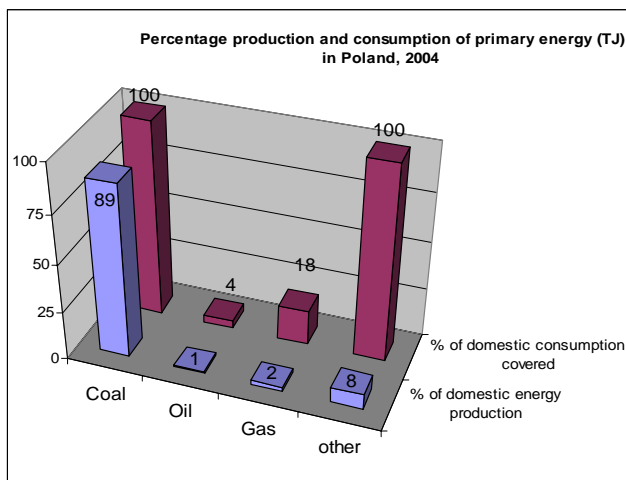
Coal may also be used as a feedstock to produce gas equivalent to pipeline natural gas. Technology involved is not as burdensome as in case of CTL; the first step is also coal gasification, but then syngas is converted to methane in a reactor and the product is adjusted to meet the specifications for pipeline gas.

According to a preliminary assessment made by the Central Mining Institute, a SNG installation processing 5 MT of coal into 2 billion m³/y of substitute gas would require an investment of \$1.7 M. However, its competitiveness depends on the liberalisation of gas prices in Poland.

Source: K. Stańczyk, K. Kapusta, E. Jędrzyk, „Ocena zasadności wytwarzania substytutu gazu ziemnego (SNG) na bazie węgla kamiennego w Polsce”, paper submitted for publication in *Przemysł Chemiczny*.

At the same time Poland has large proven reserves of coal (15.7 BT) and is a large coal producer (with output around 100 MT per year). The processing of coal into liquid fuels or synthetic natural gas (SNG) could help the domestic mining industry by increasing liquidity and lessening Polish dependence on imports of energy resources.

Figure 2: Production and consumption of primary energy in Poland, 2004



Source: „Bezpośrednie upłynianie węgla jako perspektywa otrzymania paliw ciekłych w Polsce”, *Chemik*, 6/2007, p. 304.

The processing of coal into liquid fuels or synthetic natural gas (SNG) could help the domestic mining industry by increasing liquidity and lessening Polish dependence on imports of energy resources.

It is important to note that whereas in case of oil there are possibilities of alternative supplies through the Gdańsk oil port, and an alternative route to deliver oil from the Caspian region (the Odessa-Brody-Płock pipeline) is actively pursued, there is practically no other choice for natural gas deliveries for the moment except via the existing pipelines from Russia.

Nevertheless, several options for gas supply diversification are considered:

¹⁵ „Bezpieczeństwo Energetyczne Polski”, Raport BBN, Bezpieczeństwo Narodowe, 1/2006.

construction of a LNG terminal, connection to Norwegian sources (the Baltic pipe), joining the Nabucco project, extension of interconnectors. It seems that the processing of coal into synthetic natural gas could contribute significantly to Poland's energy security.

In this context, it is important to exclude the possibility of oversupply, especially when the fact that gas supply contracts are on a long-term basis is taken into account.¹⁶ It must be emphasised that although Russian energy resources are associated with high political risk, they are delivered at a very competitive price and their supply is in the economic interest of Poland. Finally, limiting consumption by increased efficiency should also find due attention.

b) Coal liquefaction in Poland

A Fischer-Tropsch liquefaction plant was operated in Poland (Oświęcim) as a remnant of Germany's wartime production, but it was closed down in the 50s. In 1967 the Central Mining Institute (GIG) started research on a two-stage direct liquefaction, later concentrating on the one-stage process. Due to the lack of financial resources and the uncertain future of coal mining in the early transition period in Poland, the (planned for 1991) 200 T/d pilot plant was not implemented. In 2006 research was renewed, focusing on direct coal hydrogenation under moderate pressure. Also ICHPW (Institute of Chemical Processing of Coal) and leading academic centres (Scientific-Technical Committee – AGH University of Science and Technology, Mineral and Energy Economy Research Institute; Institute of Economics – Polish Academy of Science PAN, The Silesian University of Technology) have engaged in research on coal technologies, including gasification and liquefaction. Kompania Węglowa, the Polish Coal Holding, is now considering the construction of a liquefaction facility.

c) The coal market in Poland

Even though economic restructuring has involved employment and capacities reductions, Poland is still a large coal producer. In 2006, 94 MT of hard coal and 61.5 MT of lignite were produced, and 16 MT of hard coal were exported.

The “Strategy for coal mining industry in Poland 2007-2015” sees coal as an important source of energy, indicating also possibilities of chemical coal processing. Nevertheless, the Polish mining industry faces serious challenges. High fixed production costs (75%) and disproportionately high rail transportation costs (the latter account for 31% of coal price in Polish ports) contribute substantially to difficult financial standing. Though energy reserves are large, the ones which are ready for immediate use without further investment are expected to last for only 25 years.

The government should strive to restructure the sector and help it to become profitable and self-sustainable. Investment in clean coal technologies would considerably help meet environmental demands (Kyoto Protocol and EU regulations), as Polish electricity will for many years remain coal-based. A sound balance between energy security and economic considerations has to be found.

¹⁶ Compare: S. Rychlicki, J. Siemek, “Import gazu oraz analiza celowości jego wzrostu”, SITG, <<http://www.sitg.pl/4impgaz.doc>>.

d) CTL plant investment costs: Estimates in Polish conditions

There are some factors which significantly influence the profitability of CTL plants:

- *Prices of crude oil* on the international markets;
- *Prices of coal* as a feedstock;
- *Capacity* of the plant;
- *Plant availability* (reliability of plant operation, output and operational costs that meet the assumptions of the design);
- *High capital costs* and long period of return on investment;
- Costs of meeting *environmental requirements* (e.g., CO₂ capture and storage or costs of emissions).

Rough estimates carried out in 2006 by the Polish Central Mining Institute (GIG) indicate that investment costs for a liquefaction installation of a 3 MT/year capacity¹⁷ range between \$4.5-5.5 billion. Assuming coal price of \$54 per T, this installation (based on direct liquefaction technology) could produce liquid fuels at a cost of \$45-50 per bbl.¹⁸ Almost half of the investment costs of this technology account for the hydrogenation facility and the costs of hydrogen production. Technological advances, application of underground coal gasification or – alternatively - coupling the liquefaction plant to a nuclear power plant to use waste heat, could substantially decrease costs.¹⁹

Prof. Włodzimierz Kotowski from Opole University of Technology has produced estimates for a Fischer-Tropsch liquefaction plant located in Oświęcim at the chemical plant “Dwory”. Estimated costs are €1.7-2 billion (\$2.3-2.7 billion) and construction time would be 3 to 4 years. EU financial support is deemed possible. This liquefaction plant should process 9 MT of coal to produce 3 MT of liquid fuels and additionally 0.37 MT of ethylene, 0.172 MT of chemicals, 0.2 MT of ammonia and 0.18 MT of sulphur per year. Assuming a coal price of €38 per T (\$52), the average price of high-octane gasoline should be €0.64 per l (\$0.88). The idea found interest at Kompania Węglowa and the Chemical Company “Dwory.”²⁰

Kompania Węglowa has also considered the construction of a coal liquefaction plant based on a modified indirect Fischer-Tropsch method. The industrial area of the former Cieczott coal mining plant (Silesia, Oświęcim region) was regarded as a tentative place for the installation, as it would provide some necessary infrastructure. Also coal supplies of appropriate quantity and quality could be delivered by the mines “Piast” and “Ziemowit” located nearby.²¹ In addition, foreign companies like Shell and ThyssenKrupp have reportedly shown interest in that sort of enterprise, declaring plans to construct an

¹⁷ Smaller installations are regarded as not profitable.

¹⁸ J. Świądrowski, “Techniczna i ekonomiczna ocena możliwości wdrożenia technologii upłynniania węgla w Polsce”, GIG, materiały informacyjne.

¹⁹ J. Świądrowski, A. Rejman-Burzyńska, E. Jędrzyk, op. cit., p. 308-309.

²⁰ “Notatka na temat technologii produkcji paliw silnikowych z węgla wg artykułu prof. Włodzimierza Kotowskiego, Czysta Energia I/2006”, Energetics Department, Republic of Poland, Ministry of Economy, p. 3.

²¹ “Notatka na temat stanu prac w Agencji Rozwoju Przemysłu ARP S.A. w zakresie rozpoznawania technologii zgazowania węgla wg pisma ARP z dnia 22.09.2006 znak ARP/ZARZ-EEN/707/206 do Min. Ministra Woźniaka”, Energetics Department, Republic of Poland, Ministry of Economy.

installation for coal gasification for electricity, liquid fuels and chemicals (investment was reported in the range of €1-3 million).²²

It is necessary to emphasise again, that only a detailed study taking into account site-specific conditions, may assess the feasibility of a liquefaction plant in Poland. However, available studies may provide useful insights (see references).

e) **Economic implications of establishing CTL industry in Poland**

Establishing coal liquefaction industry in Poland would have significant implications for the economy of the country.

Budgetary costs:

- Costs of *investment incentives* and *risk of loan guarantees* (if provided).
- Costs of *operational guarantees* (e.g. off-take agreement, if provided).
- *Lower fiscal gains from fuel excise* for CTL fuels (if provided).

Other costs:

- In case of a *long term oil price stabilisation at a level lower than breakeven price*, expensive synthetic fuels would be a burden to citizens and would *reduce competitiveness of economy*.
- If CCS technology does not become available on a commercial scale at the time of plant delivery and if chemical coal processing is to be included in CO₂ emissions limits, then except for a *substantial increase in the price of synthetic fuels* it might use *significant amount of emission rights allocated to Poland*.
- Funds necessary for *cost of related investment* (if applicable, e.g., transportation issues – pipelines for produced fuels, refineries).

Benefits:

- Considerable improvement in *foreign exchange balance*.
- Significant influence on *stabilisation of fuel prices*, protecting against high volatility.
- Benefits to *coal mining industry*:
 - Use of lower quality coal which is not competitive on the market.
 - Increase in coal production, which decreases price of coal. This improves export competitiveness and decreases price of feedstock for power generation.
 - If coal for liquefaction offsets coal for exports, then high railway transport costs are avoided.

The regulatory framework might put in question the profitability of synfuels, as large **carbon dioxide emissions** (around 700 kg of CO₂ per barrel) may result in a **price penalty**. Although current prices of CO₂ in the EU Emission Trading Scheme are €0.10 per T, futures for December 2008 oscillate around €20 per T.

A solution to this problem may be the **CCS technology**, however there is an efficiency and a product penalty (respectively 4% and 3%, without costs of sequestration, in case of University of Kentucky study). Application of CCS might lead to substantial reduction of sequestration costs over time (learning curve).

²² "Kolejka po unijne pieniądze. Paliwa z węgla", GIPH, <http://www.giph.com.pl/archiwum/135_1.html>.

- *Employment:*
 - Employment of coal miners to produce 8 to 10 MT/y of coal required for liquefaction purposes (approximately 5,000 people).
 - Employment of staff to operate the liquefaction plant (around 600, estimates of *Kentucky study*).²³
 - Employment of construction workers (around 3,650, estimates of *Kentucky study*).
- *Science:*
 - Use and development of the scientific potential of Polish universities and research institutes.
 - A significant support for the establishment of a Clean Coal Cluster in Silesia and the strengthening of its image.
 - CTL industry might be a gateway to hydrogen economy.
- *Tax income:* Taxes paid by CTL and related industries.
- *Related investment* (magnifier principle) and *development of other related industries* (e.g. chemical plants using CTL products other than fuel, mining equipment).
- Provision of *high quality fuel* for the Polish market.

²³ “Technologies for Producing Transportation Fuels, Chemicals, Synthetic Natural Gas and Electricity from the Gasification of Kentucky Coal”, University of Kentucky, Center for Applied Energy Research, July 2007.

4. Conclusions and Recommendations

Synfuels seem to be a viable alternative to provide either liquid fuels or synthetic natural gas. Though the “trigger price” for the CTL industry seems to have been reached, the biggest challenges are high investment costs and a risk of oil price stabilisation at a low level. The following actions should be pursued:

1. *A long-term strategy for the diversification of energy resources* in Poland *should* seriously consider and *include options of coal-derived liquid fuels and substitute natural gas*.
2. A *detailed feasibility study is essential* to assess the possibilities of developing liquefaction industry in Poland, to choose technology provider and to make decisions about potential investment.
3. Though there are currently no possibilities to diversify gas supplies, some alternatives are under development. *SNG might be an option to provide domestic sources of gas*, yet due care should be taken to avoid over-contracting.
4. *Research in clean coal technologies is crucial*. Therefore adequate funds should be provided at national level and at the same time Polish universities and research institutes should actively participate in EU framework research programmes, making sure that clean coal technologies are on the research agenda. A pilot liquefaction plant could provide valuable experience.
5. Commercial application and operational experience should decrease the cost of synfuels production. Therefore *development in CTL and SNG industry should be closely monitored* and best practices identified.
6. *A CTL industry is unlikely to start operating without government support*. To avoid the risk associated with loan guarantees it seems that reduced excise tax on synthetic fuels is the best option. However, this approach would mean reduced tax income in the long run.
7. If a feasibility study shows the commercial viability of a CTL plant, then a *consortium consisting of a state owned company* or companies (possibly PKN Orlen, PGNiG, Lotos, Kompania Węglowa) *and of a reputable engineering, procurement and construction (EPC) company* should be created. State-owned entities would guarantee that energy security aspects of CTL will be taken into account. A “wrap-around” warranty for the overall configuration is desirable, though it might be hard to obtain.

Appendix

Table 2: Technologies of direct liquefaction regarded as most likely to find commercial application

Kohleol , Ruhrkohle AG, Germany	Modified Bergius process, tested in a 200 t/d study plant in Bottrop
NEDOL , NEDO, Japan	One stage, direct liquefaction process, tested in a 150 t/d study plant in Kashima
CTSL , HTI, USA	Catalytic Two-Stage Liquefaction process based on the H-coal technology, tested in a 6 t/d study plant in Wilsonville
LSE , British Coal Corporation, UK	Liquid Solvent Extraction, a two stage process tested in a 2,5 t/d study plant in Point of Ayr
BCL , NEDO, Japan	Brown Coal Liquefaction, two-stage process tested in a 50 t/d study plant in Morwell, Australia

Source: "Bezpośrednie upłynnianie węgla jako perspektywa otrzymywania paliw ciekłych w Polsce", Chemik, 6/2007, p. 305.

References

Available CTL studies:

- “A Feasibility Study for the Construction of a Fischer-Tropsch Liquid Fuels Production Plant with Power Co-Production at NSA Crane (Naval Support Activity Crane)”, A report prepared for Crane Technology Incorporated under the sponsorship of the United States Department of Labor, May 31 2007.
- “Baseline Technical and Economic Assessment of a Commercial Scale Fischer-Tropsch Liquids Facility”, DOE/NETL-2007/1260, April 9, 2007.
- “Technical and Economic Assessment of Small-Scale Fischer-Tropsch Liquids Facilities”, DOE/NETL-2007/1253, February 27 2007.
- “Technologies for Producing Transportation Fuels, Chemicals, Synthetic Natural Gas and Electricity from the Gasification of Kentucky Coal”, University of Kentucky, Center for Applied Energy Research, July 2007.
- “Possible reforms to the fiscal regime applicable to windfall profits in South Africa's liquid fuel energy sector, with particular reference to the synthetic fuel industry”, report prepared by a task team appointed by the Minister of Finance of RSA, 9th February 2007.

Reports and Articles

- “Bezpieczeństwo Energetyczne Polski”, Raport BBN, Bezpieczeństwo Narodowe, 1/2006.
- “Bezpieczeństwo energetyczne Polski”, Rurociągi, nr 5/2006.
- “Coal. Issues and options in a carbon-constrained world”, Optima, February 2005
- “Coal: Liquid Fuels”, World Coal Institute, 2006.
- “Coal: Secure Energy”, World Coal Institute, 2005.
- “Import gazu oraz analiza celowości jego wzrostu”, S. Rychlicki, J. Siemek, SITG, <<http://www.sitg.pl/4impgaz.doc>>.
- “Notatka na temat technologii produkcji paliw silnikowych z węgla wg artykułu prof. Włodzimierza Kotowskiego, Czysta Energia 1/2006”, Energetics Department, Republic of Poland, Ministry of Economy.
- “Policy implications for CTL in the USA”, R. Bezdek, in: “Coal-to-liquids. An alternative oil supply?” CIAB Workshop Report, IEA, November 2006.
- “Policy issues for Coal-to-Liquid Development”, J.T. Bartis, RAND Corporation, May 2007.
- “Strategia działalności górnictwa węgla kamiennego w Polsce w latach 2007-2015”, Warszawa, June 2007.
- “Terminale skroplonego gazu ziemnego – krok w stronę mniejszego uzależnienia od dostaw tego surowca do Polski”, E. Kochanek, Bezpieczeństwo Narodowe, 2007/3/4.
- “World Energy Outlook 2006”, IEA.
- „Bezpośrednie upłynnianie węgla jako perspektywa otrzymywania paliw ciekłych w Polsce” (Direct liquefaction of coal as perspective source of liquid fuel for Poland); J. Świądrowski, A. Rejman-Burzyńska, E. Jędrzyk, Chemik, p. 303, N0 6, Vol. LX (2007).
- „Driving without Petroleum?”, Energy Charter Secretariat, May 2007.
- „Economic impact of liquid fuel mitigation options”, R.H. Bezdek, R.M. Wendling, Management Information Services, Inc, Washington, February 2006.
- „Notatka na temat stanu prac w Agencji Rozwoju Przemysłu ARP S.A. w zakresie rozpoznawania technologii zgazowania węgla wg pisma ARP z dnia 22.09.2006 znak ARP/ZARZ-EEN/707/206 do Min. Ministra Woźniaka”, Energetics Department, Republic of Poland, Ministry of Economy.

- „Ocena zasadności wytwarzania substytutu gazu ziemnego (SNG) na bazie węgla kamiennego w Polsce” (Assessment of feasibility of Substitute Natural Gas (SNG) production from coal in Poland), K. Stańczyk, K. Kapusta, E. Jędrzyk, paper submitted for publication in *Przemysł Chemiczny*.
- „Perspektywy węgla w gospodarce świata i Polski – szanse polskiego górnictwa w Unii Europejskiej”, W. Blaschke, *Polityka Energetyczna*, tom 8, zeszyt specjalny, 2005.
- „Przechwytywanie i magazynowanie CO₂ – technologie CCS”, J. Malko, H. Wojciechowski, *Wokół Energetyki*, June 2007.
- „Techniczna i ekonomiczna ocena możliwości wdrożenia technologii upłynniania węgla w Polsce”, GIG, materiały informacyjne.
- *The coal resource. A comprehensive overview of coal.*, World Coal Institute, 2005.

Press releases

- “Kolejka po unijne pieniądze. Paliwa z węgla.”, GIPH, <http://www.giph.com.pl/archiwum/135_1.html>.
- „Sasol – zgazyfikowanie węgla”, R. Miszkiel, *Rurociągi* Nr 1/42/2006.
- „SPECIAL REPORT: Fischer-Tropsch oil-from-coal promising as transport fuel”, *Oil & Gas Journal*, February 26, 2007.
- *Introduction of senator Bunning of Coal-to-liquids Promotion Act of 2007*, <http://www.futurecoalfuels.org/documents/010507_bunning_introduction.pdf>.
- Xinghua net, China Daily press release.

Acronyms and Abbreviations

BTL	Biomass-to-liquids
CCS	Carbon Capture and Storage
CNG	Compressed Natural Gas
CTL	Coal-to-liquids
F-T	Fischer-Tropsch
GTL	Gas-to-liquids
LPG	Liquefied Petroleum Gas
SNG	Synthetic Natural Gas
bb/d	barrels per day
M	Million
B	Billion
T	Tonne
L	Litre