STRATEGY TO MAXIMIZING THE USE OF COAL AND ASSOCIATED GASEOUS FUELS IN SOUTH SUMATERA BASIN

BUKIN DAULAY, DATIN F. UMAR, BINARKO SANTOSO and SUGANAL
R & D Centre for Mineral and Coal Technology
Jalan Jenderal Sudirman 623 Bandung 40211
Ph. 022-6030483, fax. 022-6003373,
e-mail: bukin@tekmira.esdm.go.id; binarkos@tekmira.esdm.go.id

ABSTRACT

South Sumatera Basin has been known as one of the most promising sedimentary basins in Indonesia. This basin has large coal resources and is currently also believed to have an enormous amount of coalbed methane (CBM) resources. The coal seam in the basin is considerably thick and continuous, low ash and sulphur contents and could be found at favourable depth for CBM development. Coal seams can be exploited by traditional mining methods, which are open cut and underground minings. When the coal seam is not economic to exploit using traditional method, underground coal gasification (UCG) technology could be implemented to optimize the use of coal and associated gaseous fuels in the basin. However, CBM operation has to be conducted before UCG operation.

South Sumatera coal could be utilized for direct combustion in mine site in order to reduce transport cost; could be upgraded to obtain high calorific value coal or converted to gas, liquid and coke fuels through gasification, liquefaction and carbonization technologies.

Keywords: South Sumatera, Coal, CBM, UCG

INTRODUCTION

South Sumatera Basin situated in South Sumatera Province is blessed with abundant fossil resources. In the past, oil and gas producers flocked the province to find oil and gas wells. Nowadays, despite that its oil and gas reserves have been declining, the region is still attracting investors for its huge amount of potential coal resources as well as its associated CBM. This province holds the largest coal resources, followed by East and South Kalimantan Provinces as shown in Figure 1 (Centre for Geological Resources, 2009). However, South Sumatera lags far behind the other two provinces in terms of production. The main reason for this obstacle is the transportation network and the low quality of more than 75% of the coal deposits indicating by high moisture content, up to 60% and low calorific value.

South Sumatera Province has been proclaimed as the national energy barn. However, the fulfilment of energy needs in this province faces many dilemmatic obstacles, among others, difficulties in supplying natural gas to fertilizer plants, the lack of low-cost energy for households sector and also the low reliability of the electricity system. The magnitude of coal potency as fuel in power plant does not guarantee electricity in South Sumatera that has high levels of reliability, quite the opposite this area frequently experience power failure. These contradictory conditions occur because of lack of energy management system and the availability of appropriate infrastructure. This paper intends to discuss the strategy of how to maximize coal use and associated gaseous fuels in the basin.

SOUTH SUMATERA COAL INDUSTRY

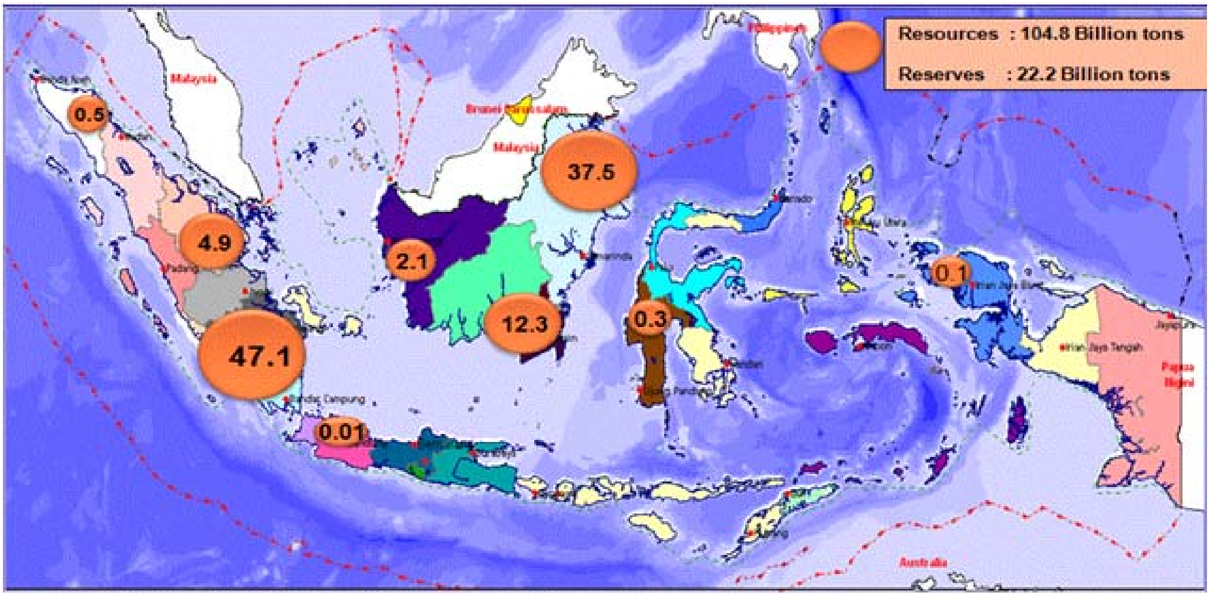
Tertiary sediments in South Sumatera were deposited in the foreland South Sumatera Basin. This basin forms part of the Muara Enim Anticlinorium. Two periods of sedimentation took place in the basin, namely transgressive and regressive phases (Gafoer et al., 2007). The Telisa Group consisting

Received : 25 January 2010, first revision : 08 July 2010, second revision : 29 September 2010, accepted : October 2010

of Talang Akar, Baturaja and Gumai Formations was deposited during the transgressive phase and the regressive phase resulted in deposition of the Palembang Group consisting of Air Benakat, Muara Enim and Kasai Formations. The workable coal measures of the basin are developed in the Muara Enim Formation, which occurs in the middle of the Palembang Group. The thickness of this formation is 250 – 800 metres with the age of Late Miocene to Pliocene (Table 1). Individual prospective seams within the basin have been reported to have thicknesses of up to 17 metres, although a seam thickness of between 5 and 8 metres is closer to the norm throughout the area.

In South Sumatera, there are two groups of coal producers based on types of permits. They are Coal Contract of Work (CCoW), consisting second and third generations (about 10 companies) and mining authorization (KP) holders, including KP for Cooperative Units (more than 150 companies).

Currently, South Sumatera coal resources are estimated at 47.1 billion tons (Figure 1). It is about 90% of the total coal resources found in Sumatera island or 44.9% of national total coal resources (Centre for Geological Resources, 2009). Coal deposits are widely distributed in many locations



Source: Centre for Geological Resources (2009)

Figure 1. Indonesia coal resources by provinces

Table 1. Stratigraphy of South Sumatera Basin (Gafoer *et. al,* 2007)

Formation	Age	Thickness (m)	Lithology
Kasai	Pliocene	>200	Tuff, tuffaceous sandstone and claystone
Muara Enim	Mio-Pliocene	250 – 800	Claystone intercalated with sandstone, coal and siltstone
Air Benakat	Late Miocene	300 – 600	Claystone intercalated with glauconitic sandstone, abundant foraminifers
Gumai	Middle Miocene	150 – 1.500	Claystone intercalated with sandstone and siltstone
Baturaja	Early Miocene	50 – 200	Limestone
Talang Akar	Late Oligocene	400 – 850	Interbedded sandstone and shale, coarse to very coarse sandstone intercalated with coal and siltstone

in South Sumatera Province, among others in Muara Enim, Lahat, Musi Banyuasin, Banyuasin and Musi Rawas Regencies. The coal reserves account to 4.9 billion tons or only about 22% of the total national coal reserves.

Production of coal from South Sumatera is very small compared with the total national coal production; and it mainly comes from Muara Enim Regency operated by PT Tambang Batubara Bukit Asam (PTBA). Coal production increases slightly every year. In year 2006, coal production was about 8.7 million tons and increased to 11.6 million tons in 2009 or only about 4.5% of total national coal production (Directorate General of Mineral, Coal and Geothermal, 2009). More than 50% of the coal production is allocated for domestic use, particularly for electricity, and the rest is for export market. Future coal production levels will continue to rise considerably due to increase domestic demand from electricity utilities and other uses.

METHODOLOGY

Quality of the coal is evaluated based on its petrographic characteristics, which are governed by two essentially independent concept; they are coal rank and coal type. Coal rank is determined based on vitrinite reflectance, while coal type is related to maceral (vitrinite, inertinite and liptinite) content. Rank is related to degree of coalification that is started from peat through anthracite and it is tested with many parameters; one of them is vitrinite reflectance. Type is related to the physical properties that is determined by its maceral composition; they are vitrinite, inertinite and liptinite.

The coal samples for this study were collected from borehole cores and spot samples of the South Sumatera coalfield. The procedures, preparation, terminology and techniques used for the study are according to the ASTM (2002).

Petrographic studies were conducted on polished resin bound particulate pellets using Leitz microscopes with both reflected white and reflected ultra violet lights in oil immersion techniques and final magnification of 500 times.

The coal samples were prepared for petrographic examination according to the techniques developed in the Coal Laboratory, Research and Development Centre for Mineral and Coal Technology, Bandung.

The method of preparation of polished particulate coal mounts for microscopic analysis includes crushing, embedding, grinding and polishing. The microscopic examination of the polished blocks was undertaken by using a reflected light Leitz Orthoplan microscope fitted with a fluorescence mode.

The maceral analysis is based on counting of 500 points using the Swift Automatic Point Counter attached to the microscope. The maceral data are calculated as follows:

- mineral matter counted : % vitrinite + exinite + inertinite + mineral matter = 100
- mineral matter free basis : % vitrinite + exinite + inertinite = 100

The measurements on vitrinite reflectance were carried out based on 100 points obtained on each sample from which the mean random reflectance (Rvrnd) and the standard deviation (s) were calculated. In addition, a total of 30 measurements were taken on each sample from which the mean maximum reflectance (Rvmax) and deviation (s) were also calculated.

Secondary data of geological features, potential CBM resources and coal chemical analysis of South Sumatera Basin are also evaluated for determining the strategy of how to maximize coal use and associated gaseous fuels in the basin.

RESULTS

Petrographic Characteristics

Vitrinite reflectances of South Sumatera coal range from 0.30 to 2.60% (lignite-anthracite). The wide rank variation of the coals in this area is a result of higher regional coalification level in the basin associated with the local and variable effects of igneous intrusions; for example, intrusion of the Pliocene-Pleistocene andesitic body in the Bukit Asam and Bukit Kendi areas (Muara Enim Regency), as well as the greater cover or overburden. Vitrinite reflectances of the coal not affected by contact alteration range from 0.30 to 0.53% (lignite-subbituminous), but the reflectances of thermally altered coals range from 0.69 to 2.60% (high volatile bituminous-anthracite). Vitrinite reflectances between 0.40% and 0.50% are dominant at the Bukit Asam area. Coal with low vitrinite reflectance (0.30% or less) is normally present far from the intrusive body.

Vitrinite is the main maceral composition in the coals, followed by liptinite and inertinite (Figure 2). Typical vitrinite, liptinite and inertinite contents of the coals are 76-96% (average of 87%), 2-15% (average of 7%) and <5%, respectively. Basically, the type of maceral has existed during the coal formation. Therefore, there is no maceral composition change during coalification stage. High vitrinite contents found in some thermally altered coals may be due to the difficulty of distinguishing vitrinite from other macerals. Mineral content consisting mainly of silica, carbonate and pyrite that reflect the ash content of the coal is normally low (average <5%).

Strategy of Coal Development

In order to maximize use of coal and associated gaseous fuels in South Sumatera Basin, the following development concept has been identified (Figure 3).

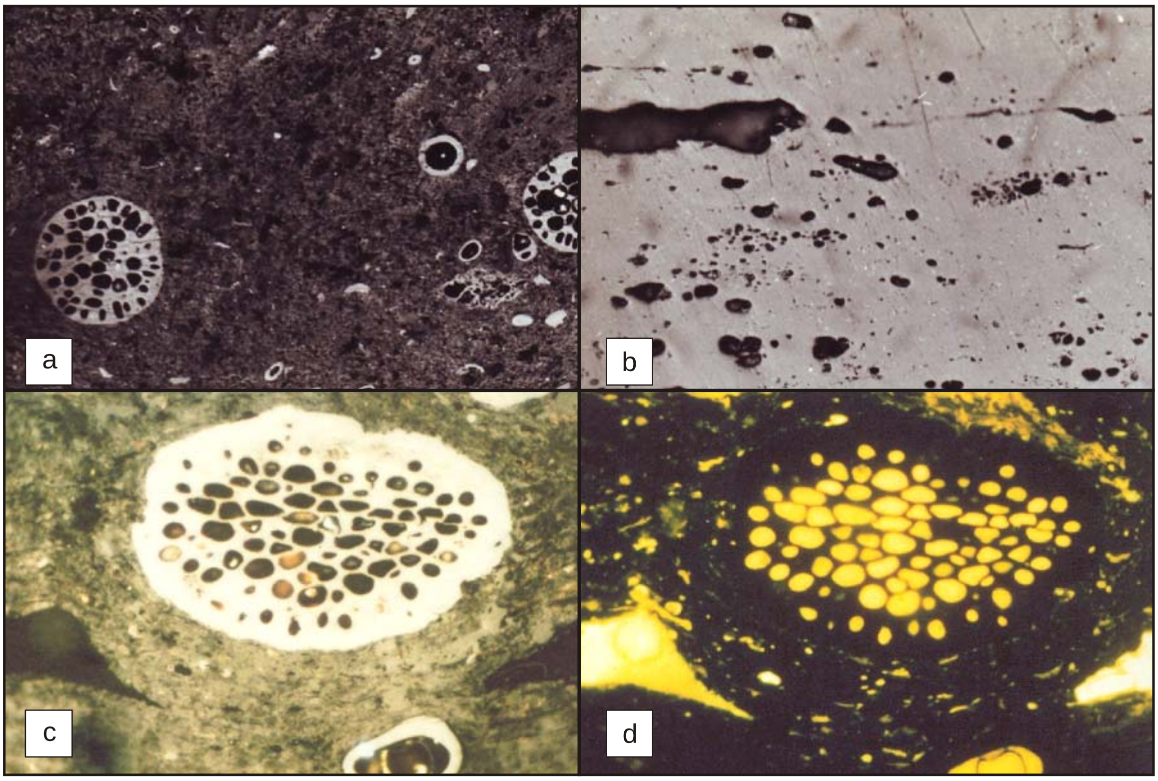


Figure 2. Macerals of the South Sumateran coals

a. Detrovitrinite matrix (blackish grey) and sclerotinite (white) in coal not affected by contact alteration. Rvmax=0.41%, field width=0.36 mm, reflected white light
b. Vitrinite of thermally affected coal (light grey). Rvmax=2.28%, field width=0.22 mm, reflected white light
c. Resinite (black, rounded) infilling cells in sclerotinite (white). Rvmax=0.38%, field width=0.28 mm
d. As for Figure c, but in fluorescence mode

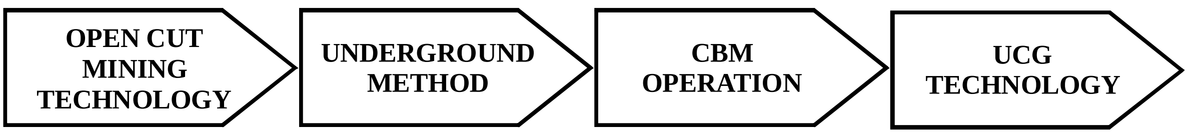


Figure 3. Sequences of exploiting coal and associated gaseous fuels

Coal mining method will be judged based on overall geologic aspects, including the depth of cover to the coal seam, number and thickness of coal seams, geologic structures (faulting, folding and igneous dyke/sill), strength of all the various strata above and immediately below coal seam, water table, permeability of possible aquifers and the presence of gas either carbon dioxide or methane. The final goal of the above basic issues is how the coal can be extracted at the minimum cost.

Currently, coal deposit in the province is being exploited with open cut mining technique. However, in the future when the coal seam becomes deeper, it has to be operated by underground method. If the underground mining method is not accessible anymore, UCG technique can be implemented. However, in order to maximize use of coal and associated gaseous fuels, integrate CBM operation can be applied before UCG technology, particularly when the coal seam in depth of below 300 metres. Some of these activities are concurrent and can be integrated in time and space to match plant-life for optimal economic return. Activities of producing coal mine methane (CMM) from abandoned mines will also be conducted to reduce emission and utilize methane energy source.

- Open Cut Mining Technique

  Open cut mining technique can be considered under three basic headings, namely strip, open pit and highwall minings. The selection of the particular mining method from within these methods is based on a multitude of considerations. The matching of open cut equipment to the deposit, the operating requirements and production levels is the key to successful open cut mining. The provision of infrastructure and maintenance systems to support the selection equipment is the way in which machine availability, budgeted production of overburden and budgeted costs are achieved. Factors to be considered in selecting the mining method include mine dimensions, slopes, pit widths, strip lengths, timing requirements, maximum dragline stripping depth, coal thickness, coal recovery percentage and life of project (Harman, 1987).

  Truck and shovel and bucket wheel are the main alternative methods of overburden have to be evaluated. The principal factor influencing the choice is hardness of the overburden. Bucket wheels are suitable for relatively soft material and, truck and shovel systems can operate in harder materials. Frequently explosives are required to fracture the overburden to allow for economical removal.

  Open cut mining allows for multiple seams to be recovered that is not always possible in underground mines. The critical balance is between the number of cubic metres of overburden that has to be removed for each ton of coal recovered (stripping ratio). Even this ratio can vary depending on how thick each coal seam may be, calorific value, how hard the overburden material is and the price of the coal.

  Currently, most of the coal in the province is exploited by open pit mining technique. The stripping ratio for coal varies from 1:2 to 1:10. The lowest stripping ratio of 1:2 is normally applied for lignite or brown coal, which has vitrinite reflectance of about 0.30%. This type of coal is located mainly in Lahat, Musi Rawas, Banyuasin and Musi Banyuasin Regencies (Figure 4). Meanwhile, the highest stripping ratio of 1:10 is normally applied for coals located at adjacent of igneous intrusion, for instances at Bukit Asam and Bukit Kendi areas of Muara Enim Regency. The rank of the coal in this areas ranges between bituminous and semi-anthracite with vitrinite reflectance of >0.8%.

- Underground Method

  Currently, there is no underground mining operating coal deposits in the province. However, in the future, when the open cut mining is difficult and expensive to operate, underground mine has to be implemented. There are alternative methods for the recovery of the coal in the underground mines. For large production mines where the geological conditions in terms of safety, economy and recovery are suitable, longwall systems could be developed (Fouconnier and Kersten, 1982; Harman, 1987). The advantages of this system include saving in roof support material and labour, simpler ventilation, reduced maintenance costs and improved safety, good caving characteristics and easier roof control and high productivity as well as extraction rates. The success of the operations of longwall mining as one of the conventional underground coal mining methods is highly dependent upon the mine design and layout.

  Room and pillar mining using large powerful continuous miners is an alternative mining sys-

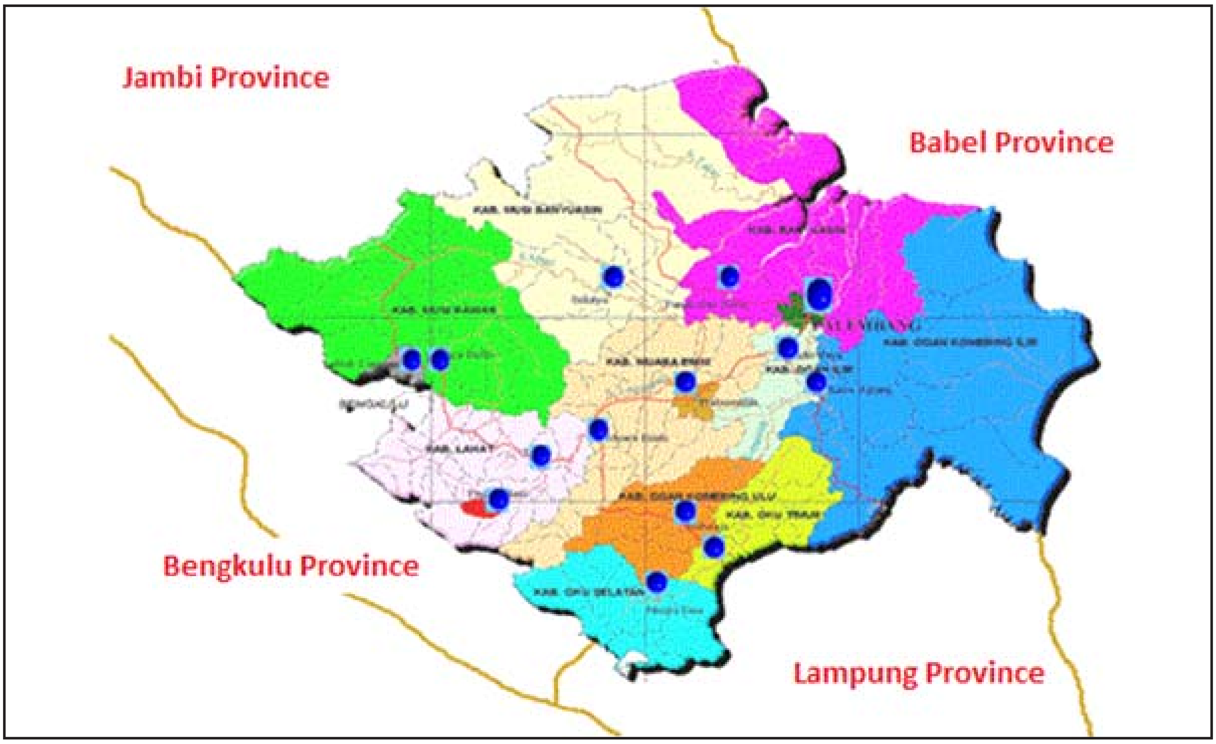


Figure 4. South Sumatera Province showing its regencies

tem, which can give the right conditions to be economical. The fundamental concept of this system is that the coal seam is divided into a regular block like array by driving through it primary headings, which are intersected at regular intervals by connecting cutthroughs.

- CBM Operation

CBM is methane-rich gas formed when plant material is converted into coal during coalification stage and stored on internal surfaces within the coal. Accumulation and distribution of CBM is controlled by geological factors, such as geologic structure, coal seam thickness and continuity, igneous intrusion, burial history and rank, hydrogeology and biogenic gas.

Typical coal in the basin is relatively low rank ranging between lignite and subbituminous with vitrinite reflectance of about 0.30% in the outcrop and shallow coal seam, but it increases with the depth of coal seam. It increases to about 0.40-0.50% at 600 metres where coal seam could become a target for CBM development. Although the coal from the basin tends to be shallow and low rank, conventional oil and gas wells that drill though the coal seams tend to experience blow outs and log gas spikes; both of these features are good indicators for CBM (Belkin *et.al*, 2009).

The successful of CBM production in the Powder River Basin in USA since 1980's, has led the CBM industry in the world to explore these types of coals (Scott and Soetoto, 2000). South Sumatera Basin is expected to be prospective for CBM development in Indonesia since coal found in this basin is very thick and has approximately similar coal rank with the Powder River Basin. Coal seam found in the Muara Enim Formation, for example, occupies about 10 to 20% thickness of this formation, which consists of 20 to 30 coal seams and the total thickness is over 30 metres. Compared with CBM, being produced in Powder River Basin, coal sedimentary basin of Miocene age in South Sumatera Basin has thicker layer, deeper depth and higher rank to some extent.

Considering that it shows at about 0.30% vitrinite reflectance of coal seam in Powder River Basin, the figure at 0.50% vitrinite reflectance of coal seam in South Sumatera Basin is considerably high. This is why South Sumatera Basin would prospective basin for

CBM development. An assessment of the potential CBM resources in South Sumatera Basin identified of 183 TCF or about 40.4% of national CBM resources of 453.3 TCF (Kurnely *et.al*, 2003; Stevens and Hadiyanto, 2004).

Framework for the development of CBM, the Indonesian Government is targetting production of 1 billion standard cubic feet per day, or about 0.18 million barrels of oil equivalent, by 2025. The Government wishes to start CBM production in 2011 for electricity that may be located at Sekayu and Tanjung Enim, South Sumatera (Satyana, 2010).

- UCG Technology

UCG is a mining technology that can efficiently convert deep, unmineable coal resource into valuable and versatile syngas that can be used to generate power or used as a feedstock in chemical plants to manufacture fertilizer, synthetic natural gas and synthetic liquid fuels. UCG operated commercially in the former Soviet Union at several sites for about 40 years (Odira Energi Persada, 2004). At one site in Uzbekistan, UCG has been producing power and ammonia, without interruption, for over 46 years. Outside the former Soviet Union, numerous UCG demonstration projects have been successfully conducted in many countries, among others the United States, China and Australia.

Technical and commercial viability of using UCG could be implemented to monetize coal resources that are currently not economic to be mined. The benefits of UCG operation include eliminates conventional coal mining and problems, reduction in operating costs and surface damage, increases exploitable reserves, needs no surface gasification facilities and reduction in capital costs, leaves gasification residuals i.e. ash underground, eliminates costs, facilities, and environmental issues associated with transport and storage of mined coal or coal gasification residuals, and reduction in overall greenhouse gas emissions and has advantages for Carbon Capture and Storage (CCS).

The UCG technology is initiated by drilling two adjacent boreholes into a coal seam (typically >100 metres of depth), and the injection and subsequent down-hole ignition of a pressurized oxidant such as oxygen/steam. The product gases from the gasification process are recovered from the second well. This initial gasification front can be readily expanded by drilling and connecting additional injection and production wells.

Based on the geology of the coal seam, overburden properties, size of the coal resources and the market for gas, the development of UCG in South Sumatera Basin is prospect. UCG consumes large amount of in-situ water in coal and is ideally suited to low rank coal (subbituminous). However, UCG has commercial risks since economics at a large scale has not yet been demonstrated in the country, although it appears to be promising. Implementation of UCG technology in the province is initiated by a coal company by conducting feasibility study and will be followed by constructing a pilot plant. UCG specific permitting regulations and related polices will be needed to promote and undertake UCG projects in Indonesia.

DISCUSSION

Coal produced from both open cut and underground minings could be utilized for direct combustion in power plants or other industries, upgraded to high heating value coal or converted to other products for example gas, liquid and semicoke (form coke) fuels. The majority of South Sumatera coals are characterized by high total moisture, low heating value, high volatile matter, low thermal efficiency, low ash melting temperature, high tendency to spontaneous combustion, high vitrinite and liptinite and hydrocarbon contents (Hutton *et al.,* 1994; Daulay and Jusmady, 2000). These coal parametres dictate how the coal will be utilized.

Based on the coal properties, direct use of the coal for power plant or others is recommended to be used close to mine site, due to high moisture content of the coal and high the tendency of spontaneous combustion. High moisture is a diluent in the coal directly reducing both specific energy and thermal efficiency of the boiler by way of the latent heat required to evaporate the water in the coal and which is lost with the flue gas. Both these effects result in an increased volume of coal to be handled affecting the capital cost of the coal plant and boiler plant and dust collecting plant. The other properties, such as ash fusion temperature can be adjusted to the design of new plant. High vitrinite, low inertinite and mineral contents of the coal indicate that the coal is very easy to burn.

Low rank coal of <3,500 kcal/kg, as received calorific value from South Sumatera can be upgraded to high calorific value coal of about 6,000 kcal/kg by reducing the moisture content of the coal. Several upgrading technologies are available such as upgraded brown coal (UBC), binderless coal briquetting (BCB) and rotary drum dryer. However, these technologies are still on demonstration stages in some places in Indonesia.

Low vitrinite reflectance (<0.4%), high reactive maceral (vitrinite+liptinite is >80% by volume), high liptinite content (about 10%) and the presence of exudatinite, oil drop and oil haze indicate that the coal contains high hydrocarbon matter and makes the coal easy to be gasified and liquified to produce oil and gas. Therefore, this type of coals is the best feed for coal liquefaction, because it can be hydrogenated perfectly. The huge coal resources in the province is also fit as feedstock for Sasol Fischer Tropsh coal to liquid technology as they require at least 2 million tons of coal resources.

High vitrinite and low inertinite contents of the coal cannot be used as a single component coke feedstock for high temperature carbonization although some coals have vitrinite reflectance of >1%, because it will produce a weak spongy coke. However, this type of coals can be carbonized to produce formed coke for foundry industry.

CONCLUSIONS

Approximately 45% of national coal resources are located in South Sumatera Province. However, its contribution to the national coal production is only about 4.5% in 2009 due to the lack of infrastuctures and the low rank of majority of coals indicating low vitinite reflectance and high moisture content. The coal seams deposited continue over large distances, with deeper seams estimated to have higher ranks due to the high heat gradient of the basin setting. In some areas, for instance at Muara Enim Regency, higher rank coal is being mined. A subbituminous coal deposit in these areas increases in rank to semianthracite as a result of igneous intrusive activity.

By considering geological condition of coal bearing formation, the extraction and use of the coal and associated gaseous fuel could be started by open cut mining, particularly those coals having low stripping ratio. When the extraction of coal is not economic for open cut mining technique, the coal will be exploited by underground method. CBM operation will be commenced in accordance or after underground mining. In order to optimize the use of coal deposit and to minimize cost production, UCG technology for producing coal gas will be implemented soon after CBM operations completed and then utilize the wells that have been drilled for CBM production.

Coal can be utilized for mine mouth power plant to fulfil the short off electricity in this Province. Upgrading technology to produce low moisture and high calorific value coal and conversion technology to produce gas, liquid and formed coke fuels can be implemented to optimize the use of coal produced from open cut and underground minings.

REFERENCES

Annual Book of American Society for Testing and Material (ASTM) Standards, 2002. *Petroleum products, lubricants and fossil fuels, gaseous fuels; coal and coke,* USA, 650 p.

Belkin, E.H., Tewalt, S.J., Hower, J.C., Stucker J.D. and O'Keefe, J.M.K., 2009. Geochemistry and petrology of selected coal samples from Sumatera, Kalimantan, Sulawesi and Papua, Indonesia. *International Journal of Coal Geology 77*, p. 260-268.

Centre for Geological Resources, 2009. *Coal resources and reserves evaluation system in Indonesia.* Centre for Geological Resources, Agency of Geology, Ministry of Energy and Mineral Resources, Bandung.

Daulay, B. and Jusmady, 2000. Potensi Batubara di wilayah Sumbagsel dan upaya pengembangannya. *Technical Magazine, No. 18,* PPPTM, Bandung.

Directorate General of Mineral, Coal and Geothermal, 2009. *Mineral, coal, geothermal and groundwater statistics, 2008.* Directorate General of Mineral, Coal and Geothermal, Ministry of Energy and Mineral Resources, Jakarta.

Fouconnier, C.J. and Kersten, R.W.O., 1982. *Increased underground extraction of coal.* The South African Institute of Mining and Metallurgy, Johannesburg.

Gafoer, S., Amin, T.C. and Purnomo, J., 2007. *Peta geologi lembar Lahat, Sumatera Selatan.* Pusat Survei Geologi, Bandung.

Harman, H.A., 1987. *Introductory mining engineering*. John Wiley and Sons, New York.

Hutton, A., Daulay, B., Herudiyanto, Nas, Ch., Pujobroto, A. and Sutarwan, H., 1994. Liptinite in Indonesian Tertiary coals. *Energy&Fuels, An American Chemical Society Journal. Vol. 8, No. 6.*

Kurnely, K., Tamtomo, B., Aprilian, S. and Doria, I., 2003. A preliminary study of development of coalbed methane (CBM) in South Sumatera. *SPE Asia Pacific Oil and Gas Conference and Exhibition*, Jakarta, Indonesia.

Odira Energi Persada, 2004. Underground coal gasification. *Material presented to PTBA Manajemen* (unpublished).

Satyana, A.H., 2010. Efforts for achieving CBM electricity 2011. *International conference and Workshop on CBM*, Palembang 8-9 Nov. 2010.

Scott, H.S. and Soetoto, W., 2000. The coalbed methane potential of Indonesia: Analogies with U.S. CBM basins. *Proceedings Southeast Asian Coal Geology*.

Stevans, S.H. and Hadiyanto, 2004. Indonesia: Coalbed methane indicators and basin evaluation. *Society of Petroleum Engineers, SPE 88630*.