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# THE ECONOMIC EVALUATION OF RESEARCH-BASED INDONESIAN COAL UTILIZATION

## *EVALUASI EKONOMI PEMANFAATAN BATUBARA INDONESIA BERDASARKAN HASIL PENELITIAN*

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**ABSTRACT**

Efforts of Indonesian Government in diversifying the available fuels from domestic coal in the forms of solid, liquid and gaseous fuels open the pissibility to overcome the depleted domestic oil reserves. Within the coming few years, Indonesia will be a net oil consumer after being the net oil importer in 2003. In the last forty years, Indonesian energy consumption was heavily depended on oil fuel. To meet the increase domestic energy demand, a large quantity of domestic coal reserves should be diversified into briquette, synthetic oil and gas as well as other non-fuel or chemical products. All these diversified products are expected to be economically competitive as well as environmental friendly using clean coal technology. This article is an evaluation on study results compilation of Indonesian coal utilization and diversification in the last 15 years.

Keywords: coal utilization, coal diversification, economic benefit, clean coal technology

***SARI***

*Upaya Pemerintah Indonesia dalam penganekaragaman bahan bakar yang dihasilkan dari cadangan batubara dalam negeri dalam bentuk bahan bakar padat, cair dan gas memberikan kemungkinan untuk mengatasi makin menurunnya cadangan minyak bumi di dalam negeri. Dalam beberapa tahun mendatang Indonesia akan menjadi konsumen minyak neto setelah menjadi pengimpor minyak neto sejak 2003. Dalam empat puluh tahun terakhir, konsumsi energi Indonesia sangat tergantung pada bahan bakar minyak. Untuk memenuhi kebutuhan energi dalam negeri yang makin meningkat, cadangan batubara dalam negeri yang berjumlah cukup besar perlu dilakukan diversifikasi dalam bentuk briket, minyak dan gas sintetis serta berbagai produk kimia. Semua produk diversifikasi ini diharapkan kompetitif baik secara ekonomi maupun dalam hal ramah lingkungan dengan menggunakan teknologi batubara bersih. Tulisan ini merupakan hasil evaluasi terhadap kompilasi hasil-hasil penelitian dalam pemanfaatan dan diversifikasi batubara Indonesia dalam 15 tahun terakhir.*

*Kata kunci: penggunaan batubara, diversifikasi batubara, manfaat ekonomi, teknologi batubara bersih*

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## INTRODUCTION

Indonesian oil reserves are still able to produce crude oil up to 10-15 years. Since 2003 Indonesia has been a net oil importer country and in 2016, it is predicted to be the real oil fuel net consumer. Another alternative energy source is coal which Indonesia owns its reserves around 28.17 billion tons from 161.34 billion tons of coal resources (Sukhiyar, 2010). At the level of 400 million tons of annual coal production, the life time would reach around 100 years. It means that the Indonesian people is given for another 100 years of energy survival with 360 million tons of present coal production per year, 70% is allocated for export purposes and the rest goes to domestic consumption.

Besides coal, Indonesia has still other energy sources namely gas in the form of natural gas-594.43 TSCF, coal bed methane-453.3 TSCF, shale gas-574 TSCF. The national gas proven reserve is 157.14 TSCF which can supply a 336MMSCF power plant for another 40 years. Such a power plant generates electricity of 56 GW or about twice of the existing State Electricity Enterprise capacity, besides supplies raw material for LNG making.

As a whole, either direct or indirect coal utilization within that period would be able to be a bridge of energy transition from the current era of fossil fuel (oil and gas) toward the new and renewable energy future era such as nuclear, bio etc.

To improve the status of the coal reserves in the intensive exploration country, it is required to face the transition period from the oil and gas era to the new and renewable energy era, using the more attractive investment incentive. The available coal is the greatest national fossil energy source that could be able to respond it within the next 100 years. It is also expected that the implementation of regional autonomy (decentralization) does not restrain the encouragement of the investment process. The encouragement of the real program of coal utilization through vertical diversification such as briquette making, gasification and liquefaction is required.

Refering to national primary energy mix in 2010, coal consumption was about 26.4% (or 281.4 million BOE) out of the total national primary energy demand around 1,066.8 million BOE (Anonymous j, 2011) and is projected to be around 22.0 - 34.6 % (627.44 – 1,487.8 million BOE) out of the total national primary energy demand of 2,852 – 4,300 million BOE in 2025 (Suhala, 2011; 2012; Ariyono, 2010). The projection of the energy demand 2011-2020 based on its respective original unit can be seen in Table 1 (Anonymous k, 2011). Total current domestic consumption of coal is about 60 million tons per annum and domestic production reached about 360 million tons of coal in 2011, but mostly for export. This national coal production will be projected up to around 560 million tons of coal in 2025. It is expected that domestic consumption in 2025 is around 60-70% of the whole coal production, and 2% then belong to liquefied coal or synthetic oil.

Indonesia coal resource is mainly distributed in Sumatera and Kalimantan. It is amounted to 161 billion tons, at which 49.2% is mainly located in the eastern and southern Kalimantan and 50,5% in southern Sumatera area (Figure 1). The rest is distributed in other areas. Characteristics of such coal reserves can be seen in Figure 2 and 3; 23% of the perform belong to a high calorific coal and the remain mostly low and moderate calorific coal or low rank coal (Figures 2 and 3).

The development program of Indonesian coal-based product diversification is on the basis of several considerations such as:

- limited reserves of Indonesian oil face increasing demand for oil fuel annually;
- since 2003, Indonesia is the net oil importer, then the supply of synthetic oil should be anticipated, especially for transportation sector;
- success of the national efforts in energy diversification and conservation should be extensively enlarged and intensified;
- existing transportation sector will still be depended on fuel;
- on an other side, there is a great amount of coal resources in Indonesia which could be utilized for the next 100 years as a bridge of energy transition from the era of oil and gas to the era of new and renewable energy sources.

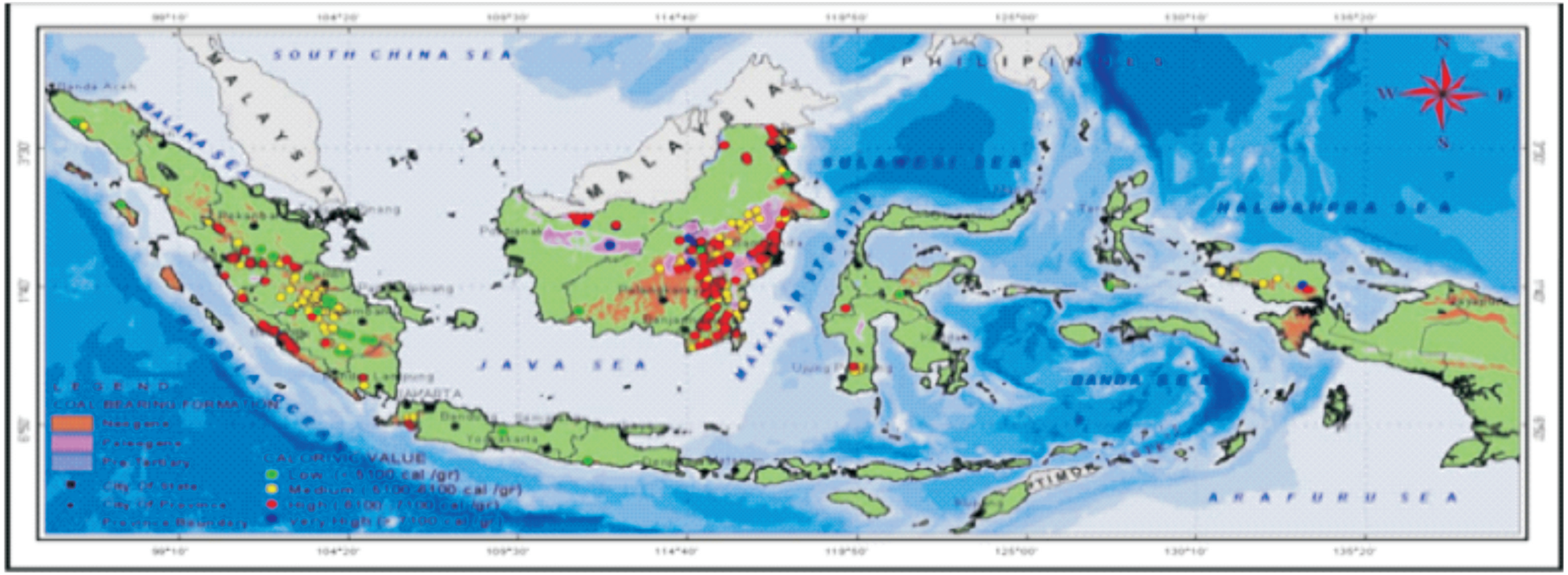
The aim and scope of the evaluation are:

- evaluating the results of investigation in coal diversification effort including coal as direct and indirect fuel and non-fuel purposes as well;

Table 1. Trend of Indonesian fuel demand, 2011-2020

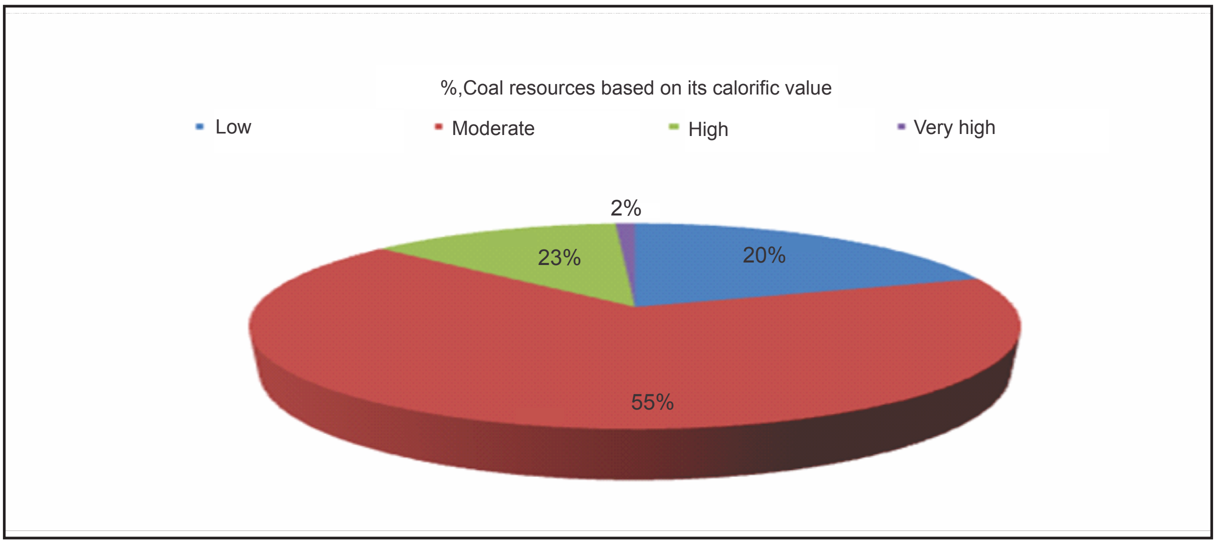
| No. | Fuel Type | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | HSD (x 10*kl) | 7.464,3 | 4.610,8 | 2.274,6 | 131,8 | 633,5 | 595,2 | 545,7 | 550,8 | 589,3 | 633,0 |
| 2 | MFO (x 10*kl) | 1.604,7 | 1.190,3 | 577,3 | 159,7 | 34,1 | 37,3 | 35,9 | 39,5 | 44,8 | 39,8 |
| 3 | Gas (bcf) | 329,8 | 337,8 | 358,4 | 365,3 | 344,3 | 341,4 | 277,1 | 197,7 | 211,1 | 227,2 |
| 4 | LNG (bcf) | - | 59,6 | 47,9 | 90,8 | 120,4 | 122,1 | 170,7 | 240,7 | 248,2 | 263,7 |
| 5 | Coal (x 10*tons) | 47.794,7 | 593254,3 | 73.788,3 | 82.954,0 | 88.754,9 | 96.002,2 | 101.442,6 | 109.263,6 | 116.691,0 | 125.737,7 |
| 6 | Biomas (x 10*tons) | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 |

*Sources: Anonymous (k), 2011.*



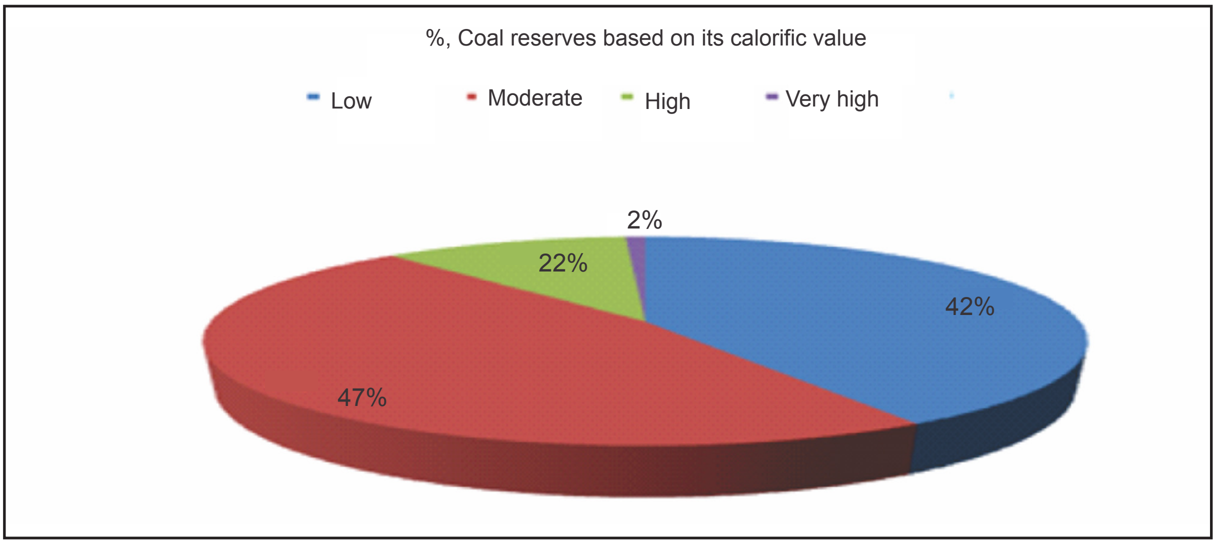

*Sources: Agency for Geology, Ministry of Energy and Mineral Resources, 2011.*
*Coal resources 161 billion tons (120 billion tons open pit & 41 billion tons underground).*
*Coal reserves 28 billion tons.*

Figure 1. Distribution of Indonesian coal resources




*Sources: Agency for Geology, Ministry of Energy and Mineral Resources, 2010.*

Figure 2. Indonesian coal resources based on its calorific value




*Sources: Agency for Geology, Ministry of Energy and Mineral Resources, 2010.*

Figure 3. Indonesian coal reserves based on its calorific value

- evaluating the financial aspects of the feasibility study (FS) results of indirect coal utilization;
- recommending views and inputs for the future detail of FS;
- looking at the effects of substitution of CO by SCO, between coke/UBC, kerosene by briquette and natural gas by producer gas;
- studying the multiply effects of the project on the regional development such as investment, added value, employment, income, output;
- studying the comparability between SCO (synthetic crude oil) and CO (crude oil), cokes and kerosene, producer gas and natural gas, such as their prices and availability.

A long effort of coal diversification in Indonesia has been carried out to face the reality that the domestic oil reserve depletion happened within the last 40 years due to the sharp increasing domestic consumption. Diversification of coal utilization includes several processes as follows:

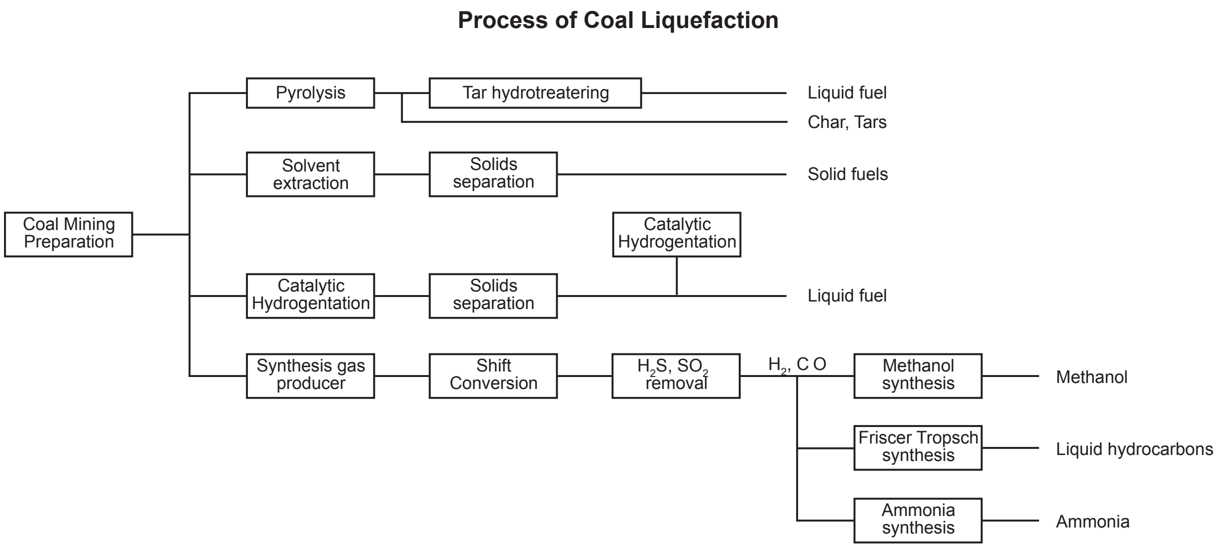
a. Direct utilization
   Coal has been used as direct fuel in industry for instance steam generating power plant, cement industry, steel plant, drying oven, small industry.

b. Indirect utilization
   i. Coking process or carbonization that is principally conducted by reducing the volatile content in coal through either direct process or double process, so that carbon increases in lieu with the increasing its porosity fixed carbon and calorific value. The coke has usually high compressive strength. Domestic consumption of cokes which is mostly for iron casting is around 140,000 tons per year but it is still imported. It is expected that domestic production of foundry cokes could be satisfied soon;

   ii. Coal gasification
   Principally, coal gasification process converts solid coal into synthetic gas that could be utilized as fuel or raw material in chemical industry. Several example processes are Lurgi fixed bed, Winkler fixed bed, Kopper-Totzek entrained bed, Tigar twin fluidized bed (Anonymous a, 2007; Anonymous c, 2000; Anonymous d, 1980; Nowacki, 1981). RDCMCT has developed direct coal gasification process for tea leaf drying and mixed oil-gas fuels;

   iii. Coal liquefaction.
   The process has four steps (Figure 4) (Anonymous d, 1980; Anonymous e, 2002; Anonymous f, 2003):
   - pyrolisis or carbonization including COED, TOSCOAL, GARRET and Clean-coke;
   - solvent extraction
     CSF (Consol Synthetic Fuel Process (CSF 2-3 : 1 solvent/coal ratio) and SRC (Pittsburgh & Midway solvent refining process) are an example for the process;
   - hydrogenation using catalyst for example H-Coal, Synthetic oil and CCL (Catalytic Coal Liquefaction) processes;
   - indirect liquefaction; and
   - new direct liquefaction using catalyst is being developed by JICA Japan.

Efforts to increase Indonesian coal added value carried out:
- in 1950s and 1960s by making a blast furnace coke that was conducted by the GOI in cooperation with Wedexro Germany;
- within 1970s and 1980s up to present by making coal briquettes to substitute fire wood, kerosene and IDO;
- in the mid 1990s up to present, by liquefying and gasificating the coal in cooperation with Japanese government (NEDO and JICA).




*Sources: (Anonymous d, 1980; Anonymous e, 2002; Anonymous f, 2003).*

Figure 4. Several flows of coal liquefaction process

## METHODOLOGY

Methodology used in this study is based on some investigation results related to:

- coal liquefaction by the Ministry of EMR in cooperation with the Agency for Assessment and Application of Technology;
- UBC (upgraded brown coal) and bio-coal conducted by Indonesian government (MEMR) and the Government of Japan (NEDO);
- other coal utilization R&D activities by *tek*MIRA – the MEMR; then analyzed by using micro- and macro-economic models substantially and furthermore reviewed how far the role of the coal diversification effort to the Indonesia economy and energy spectrum in the future.

## RESULTS AND DISCUSSION

Stages of ongoing research have been carried out by *tek*MIRA at mostly at the batch test as well as the pilot or semi commercial plant scales.

### Utilization of Coal as Indirect Fuel

Utilization of coal as indirect fuel to producing briquette, UBC, bio-coal, cokes, producer gas, synthetic oil, and coal water fuel (CWF)/coal water mixture (CWM).

### a. Semicoke- and coal briquettes

The aim of producing semi coke briquette and coal briquette is to reduce or substitute the use of kerosene and to empower the utilization of domestic coal. Several semi commercial coking plants have been developed such as at Tanjung Enim of PT Bukit Asam coal mine (10,000 tons semi coke briquette/year), Lampung (3,000 tons coal briquette/year), and Gresik (3,000 toward 150,000 tons coal).

Economic appraisal of coal briquette development as one of the alternative energy sources for oil fuel can be reviewed as follows:

- The huge burden of subsidy allocated to the oil fuel makes the government has to subsidize kerosene amounted to 82.3 million barrels of oil equivalent (BOE) or IDR 17.62 trillions. The amount of the required coal briquette equals with the value of kerosene if the exported value about US$ 1.81 billions or IDR 17.3 trillions a year. If half of the demand for kerosene in Indonesia around 5.67 million kilolitres could be substituted by coal briquette, then the substituted kerosene could be exported. This substitution will value US$ 784 millions a year in terms of export earnings;

- Based on observation of the communities it was concluded that the willingness of the consumers to get information of coal briquette looks very responsive (62.57% - 71.12 %). Lack of promotion is a constraint for coal briquette enters the market. On another side, the willingness of the respondent to come to the demonstration or familiarization event is very significant (75.72 - 80.9 %). Appropriate target of promotion has to be enforced to catch the existing potential market. The respondents expected the cheaper, odorless and cleaner coal briquettes. Therefore, the government has to conduct an optimal breakthrough of coal briquette production and effort to socialize this commodity utilization.

- Result of linear programming model of supply-demand based on the samples of coal briquette producing centers and the small industry consuming centers linkage shows that the delivered cost of coal briquette at the consumers is IDR 410-715 per kg depending on its location with average of IDR 562,50 per kg and the average price of coal briquette is IDR 575,- per kg. By considering capacity of market absorption, coal briquette price could optimally be re-calculated (Soelistijo et. al, 2003).

### b. UBC

Indonesia is the second largest coal-supplying country after Australia. The ratio of high-rank bituminous coal in the coal reserve in Indonesia, however, is still only 15% and the majority of coal is moderate- and low-rank coal. Indonesian government has the policy to work with the increasing domestic energy consumption while sustains a certain level of coal export. Technology to utilize moderate- and low-rank coal will become extremely important in realizing this policy. Multiple coal upgrading technologies besides UBC are now under development toward commercialization. However this technology is superior to others as it can process lignite with

50% or higher moisture content and it can withstand long-distance and long-hour transportation. In addition, the UBC technology is superior due to the product can immediately be used in existing power plant facilities. Then, it is expected that the technology would become widespread smoothly. (Anonymous I, 2011).

**c. Bio-coal**

Palimanan bio-coal plant which has production capacity of 5 tons/hour uses normally saw dust as biomass, bituminous coal for raw materials and a small quantity of quicklime as sulphure absorbent. Historically, results of techno-economic study on coal-briquette could be seen as follows:

1). In 2002
The optimum price of coal briquette is equal to IDR 575,- per kg and the production cost of non-subsidized kerosene is IDR 1,750 per liter. The subsidized price of kerosene at the consumer is IDR 700 per liter. Then the equivalence of 1 liter kerosene is equal to 1.4 kg briquette. It means that the coal briquette is not competitive with kerosene, but the coal briquette would be initially competitive with the non-subsidized kerosene.

2). In 2006
The optimized prize of coal briquette at the consumer is IDR 575 per kg and the subsidized price of kerosene at the consumer is IDR 2,300 per liter. The price of the non-subsidized diesel fuel is IDR 5,400 per liter. It is assured that coal briquette is competitive to kerosene and diesel oil as well.

3). Within 2010-2012
Actually the subsidized kerosene in 2010-2012 is lower than that in 2006 (IDR 4,500/liter). It is assured that coal briquette is more competitive.

**d. Foundry coke**

The upscale commercial coking plant design of producing foundry coke (coke briquette) has been carried out by *tek*MIRA at Palimanan coal center and is ready to propose for commercial industries who are interested in conducting coke-making business. If the program of domestic foundry coke production is realized, it could substitute the imported foundry coke and save the foreign exchanges about US$ 238,000 per annum for the price of the imported foundry coke around US$ 1.21 per ton and the domestic foundry coke approximately of US$ 0.53 per ton.

**e. Produced gas**

At one hand, Indonesia has an available large coal resources, but on the other hand with the ever declining and becoming less and less oil reserves, Indonesia presently has become a net oil importer. It seems that the coal needs to be utilized as oil substitute through coal diversification. *tek*MIRA has developed coal conversion technology, including coal gasification at either laboratory scale in RDCMCT or pilot plant scale in Palimanan Cirebon, West Java. The pilot plant scale is carried out in cooperation between *tek*MIRA, PT. PLN (Persero) and PT. Coal Gas Indonesia. The producer gas is used diesel fuel in dual-system diesel engine.

Historically, coal gasification has been applied since the 17$^{th}$ century and utilized for street illumination in 18$^{th}$ century. Its development was then applied at commercial scale in the 19$^{th}$ century for producing city gas. In Indonesia coal gasification for city gas was applied toward the end of 19$^{th}$ century up to the middle of 20$^{th}$ century and then is substituted by natural gas from PT. PGN (the State-owned Gas Company) up to present. Somehow, the natural gas reserves are limited if compared to coal resources in the country. In the future, initiatives to apply coal gasification and other types of gases such as coal bed methane and shale gas should be enlarged. Coal gasification technology for diesel generating power plant should also be further developed at commercial scale as well as more intensive advanced research are required.

In the case of possibility to produce producer gas at pilot plant scale, the gas has been successfully utilized as fuel gas at tea plantation to dry the tea leaves. Utilization of producer gas at such a plantation shows that around 40-50% of fuel cost can be reduced if compared with using oil fuel as calculated by Suprapto et. al (2008) for tea leaf drying at Gambung, Ciwidey. In 2003, the price of coal was IDR 400/kg, IDO oil IDR 514/kg and the fuel cost was 11-20% depending on the type of tea leaf. Fuel consumption was 40 kg coal/hour versus 20 liter of IDO oil/hour. It saved fuel of 40-50%. In 2007, the price of coal was IDR 500/kg and IDO oil IDR 5,400/liter. The cost of coal was cheaper. The investment of coal gasification for semi commercial plant was IDR 200 million with the capacity of 50 kg of coal per hour.

Effort to reduce HSD (high speed diesel oil) as fuel in diesel engine needs to be initiated to face the ever declining oil reserves in the country. This initiative has been carried out by *tek*MIRA since the middle of the last decade up to present at Palimanan coal pilot plant. The producer gas is injected into the diesel engine using venture system. South Kalimantan Sub-bituminous coal used in the gasification has calorific value around 5,500 kcal/kg (adb). Effort by produce producer gas from coal in diesel generating power plant has been developed at semi commercial plant scale. The applications is most likely techno-economically feasible. From the financial aspect benefit point of view, it shows that the dual fuel system for diesel power plant with the capacity of 250 kVA could reduce HSD consumption as many as 62.45% with the reduction of the electricity production cost is around IDR 1,119/kWh or about 47.26%. The amount constitutes the reduction of HSD savings between 25.6 – 28.8 litres per hour (Suprapto et. al, 2009).

Based on 2,800 MW diesel power plant owned by PT PLN, it will save production cost of electricity around US$ 2.74 billion per annum. Based on the assumption that the gas price is US$ 5.62/MMBTU (at the time of trial run), coal price US$ 60/ton, HSD oil IDR 7,500/liter, and the dollar rate IDR 10,000/IS$, then the average electricity production cost is IDR 2,368/kWh (using 100% of HSD oil) and IDR 1,248/kWh (for dual fuel). The average savings of electricity production cost is IDR 1,119/kWh or 47,26% as shown in Table 2.

Table 2. Average savings of electricity production cost using dual fuel and 100% HSD oil

| | | |
|---|---|---|
| 1 | HSD Oil | IDR 2,368/ kWh |
| 2 | Dual Fuel | IDR 1,248/ kWh |
| | Average savings | IDR 1,119/ kWh |

*Source: Suprapto et. al, 2009.*

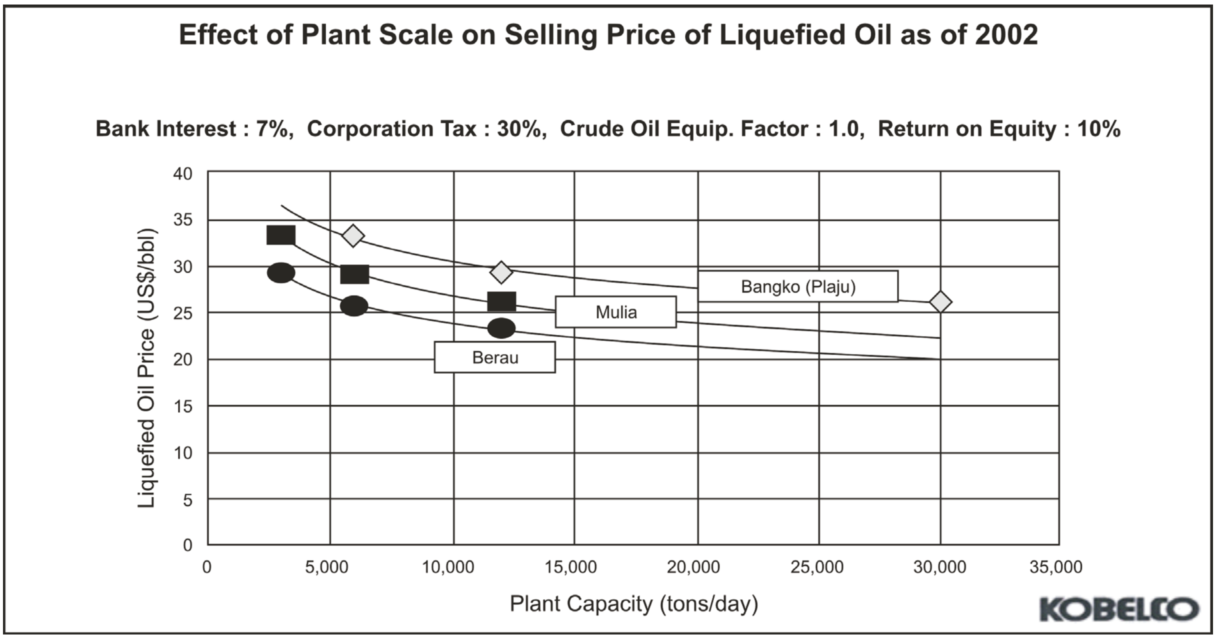
Besides the utilization of coal gasification in diesel power plant, coal gasification is used in the wider spectrum for various usages such as for producing fertilizer at PUSRI Palembang combined with natural gas or as substitute for natural gas, heating of boiler to produce steam at various plants (for instance textile factories).

**f. Synthetic oil**

The government of Indonesia (GOI) and the government of Japan, in this case BPPT (Agency for Assessment and Application of Technology, Indonesia) and NEDO (New Energy and Industrial Technology Development Organization, Japan) have launched a cooperation regard Indonesia Banko coal liquefaction program since 1994 and would probably be continued at commercial scale. Simulation of feasibility study on the plant development of 6,000, 12,000 and 30,000 tons dry coal per day respectively is just being reevaluated. This feasibility study (FS) is based on the Japan's experiences on its 0,1 ton dry coal per day bench scale unit of Banko coal liquefaction at the Kobe-steel Japan, 50 tons dry coal per day pilot plant of Victoria coal liquefaction at Morewell Victoria Australia and several pilot plant scale tests in the chain of coal liquefaction process in Japan.

Besides direct liquefaction, indirect liquefaction program is also willing to develop under MOU between Indonesia and SASOL, even though, both processes have not been continued yet. While, the present Presidential Instruction has been issued to realize that program.

Result of simulated feasibility study at the designed capacity of 6,000, 12,000 and 30,000 tons of dry coal per day with 25 years life time, shows that capacity of 30,000 tons of coal per day using coal price around US$ 13/ton would be able to produce crude synthetic oil (CSO). The CSO could competitive with the crude oil (CO), where the price of CO was about US$ 22/bbl in 2003 (Figure 5). To get price of coal as cheap as possible, "a unified coal mining and liquefaction plant unit" based on profit sharing is required to be developed. The lower the price of coal used, the more promotion the liquefaction process will be. It is more likely that CSO as an alternative energy requires certain level of incentives such as tax holiday and/or soft loan at least at the beginning of the project. The coal liquefaction program will support multiplying effects on the regional development, besides the potential positive impact of substitution of CO by CSO.




*Sources: Anonymous (e), 2002; Anonymous (f), 2003).*

Figure 5. The effect of plant scale on the production cost of Synoil (Ex Banko, Mulia and Berau Coal samples)

Moreover, financial analysis on the development of coal liquefaction in Indonesia using brown coal liquefaction (BCL) technology can be reviewed as follows (Huda et. al, 2003):

> "Financial analysis of Mulia coal liquefaction plant has been conducted in the year 2002 and up dated in the year 2007. However, the increase of coal price, currently, has promoted coal companies to export their coal rather than to allocate it as raw material for coal liquefaction. To maintain the stability of coal supply in a liquefaction plant, the use of stranded mining coal as raw material for the plant should be studied. This study was aimed to conduct financial analysis of stranded coal from South Sumatera (Pendopo Coal) and to update the financial analysis of Mulia coal liquefaction. Discounted cash flow was used as the method for the analysis. The result indicates that with the oil price higher than US$ 70/bbl and coal price below US$ 25/ton, the Internal Rate of Return (IRR) of Pendopo coal liquefaction plant achieved value higher than 10%. Reducing corporate tax from 30% to 15% increased IRR value of approximately 1%. Meanwhile, by enlarging the plant scale from 3,000t/d to 12,000 t/d will increase the IRR value as much as 5%. On the other hand, the IRR of Mulia coal liquefaction plant was less than 9% when the oil price was lower than US$ 70/bbl and coal price was above US$ 55/ton."

Furthermore, the required investment to produce CSO mainly for the transportation consumption could be seen on Table 3 (Soelistijo et. al, 2002).

Table 3. The required investment to produce CSO for the transportation sector

| | 2015 | 2025 | 2035 | 2050 |
|---|---|---|---|---|
| MMbbl | 354.69 | 485.95 | 1,249.79 | 3,214.27 |
| Investment units of 30000 tdc/d | 9 | 12 | 31 | 78 |
| Investment, MMMUS$ | 52.02 | 69.22 | 178.81 | 449.91 |

*Sources: Soelistijo, 2002, 2003.*

**g. Coal water fuel (CWF) or coal water mixture (CWM) (Umar, 2006, 2011)**

CWM technology of low rank coal through upgrading process is able to produce a relative stable fuel, easy to flow and high efficiency of combustion. CWM constitutes coal base liquid fuel that could be used for boiler fuel to substitute oil fuel, mainly heavy oil, by using the existing available boiler.

The investigation of making CWM should be continued in order to be easily found out domestically. Its utilization should also be continued at the larger scale of boiler to produce steam such as boiler in electrical power plant, textile, food and beverage industries.

Preliminary investigation resulted that:
- Composition of CWM is consisted of 80% -200 mesh of coal size, plus additives of Polystyrene sulfonate (PSS, 0,5% by weight) and Carboxymethyl cellulose (CMC, 0,01% by weight), with viscosity of less than 1000 cP.
- 1 kilolitre of oil fuel equals 2 kilolitres of CWM.
- The production cost of CWM is of about US$ 25/ton.

The development of CWM from LRC is heavily depending on the development of coal upgrading technology.

**Utilization of Coal as Non-fuel Products such as Activated Carbon and Other Chemicals**

Activated carbon is a porous carbon substance with large surface so it is very effective to be used as absorbent in various industrial refining process either in a liquid or gaseous phase (Monika, 2011).

In Indonesia, activated carbon is usually produced by using coconut shell. Coal activated carbon is imported. Up to the year of 2000 there were about 13 enterprises available, while in 2006 19 enterprise were available with the production capacity of about 44,000 tons per annum. The increasing demand of activated carbon industry in Indonesia could not be met by the limited supply of coconut shell as the main raw materials. *tek*MIRA investigation has resulted the quality of activated carbon suitable for the market demand.

Process of activated carbon production may include physical and chemical activation. Physical activation passes through carbonization (400-600° C) and activation process (900-1000°C), then chemical activation takes into chemical damping, filtering and activation at 700-1000° C. In chemical activation, prior to carbonization the raw material is impregnated with certain chemicals. Then it carbonized at lower temperatures (450-900° C).

Test of the product shows similar results with commercial ones interms of iodine number, water and ash content (Indonesia Industrial Standard (SII), 1999).

Domestic consumption of activated carbon is spread in of 42 industries, among others, petrochemical, water refining, medicine and food, sugar plant, catalyst, flue gas refining, gas purification, and shrimp husbandry (breeding). They need about 36,000 tons of activated carbon per annum.

Even though the activated carbon product has been exported but some activated carbon with certain quality are still imported for specific utilization.

In principle, chemical activation process is suitable for biomass or saw dust as raw material, whilst physical activation is suitable for coal and coconut shell.

**Economic and Environmental Analysis**

a. Economic results

1). The resumed results of coal R&D in Indonesia

The resumed potential results of coal utilization as direct and the results of coal diversification indirect ones could be seen in Figure 6. The direct utilization is the power plant, industry of cement, steel, textile and others. The potential diversified coal based products such as cokes, UBC, bio-coal, coal synthetic gas and oil, including CWM. The usages of coal as raw materials in the industry are also still open such as activated carbon.

2). Effect of inter-fuel substitution

i. Effect of synthetic oil-oil fuel substitution on the national economy

The effect of substitution of CSO on

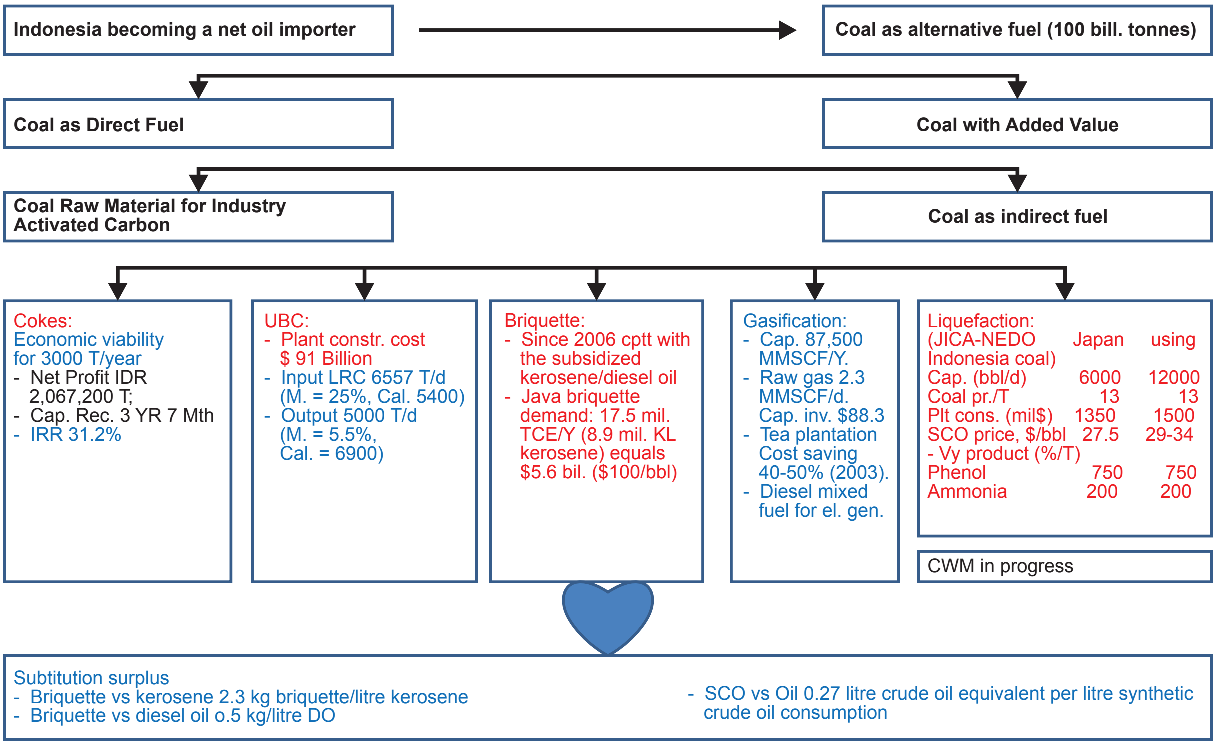



Figure 6. The current status of the Indonesian coal diversification R&D results

CO (An example: The plant capacity of 30,000 tons dry coal/day).

- In 2011, one bbl of CSO utilization (12000 t/d), the consumer would gain the surplus of about 0.27 bbl of CO equivalent.
- In 2017, no gain and no lost due to the same level of price of CSO and CO.
- In 2035, one bbl CSO utilization (12000 t/d), the consumer would get (-) 0,056 bbl CO equivalent lost.

The plant capacity of 6000 and 12000 tons dry coal/day still produces CSO with FOB greater than that of the projected CO price within the same period.

ii. Effect of dual fuel producer gas HDO (IDO)

The PLN-owned diesel power plant amounts around 3,307.16 MW which consumes oil fuel. If it utilizes dual fuel of producer gas-HDO, it would save the fuel cost of about US$ 3.24 billion per year (3,307,160 kW x 8760 hour/year x IDR 1,119/kWh x 1 US$/ IDR 10,000). The private diesel power plant in the country is not included yet.

It is obvious that an economic benefit would be gained through coal gasification for instance in the form of substitution effect (income effect plus substitution effect). This may cover a surplus gained through coal gasification by using dual fuel system (producer gas with HSD oil), if it is compared with the only HSD oil used in diesel power plant. Besides the above mentioned superiority, a certain amount of foreign exchange earnings are also gained even though only just a result of partial substitution (Suprapto et. al, 2008).

iii. Effect of briquette-oil fuel or imported cokes substitution

Several positive effects of briquette-oil substitution could be summarized as follows (Soelistijo et. al, 2003):

- Coal briquette versus kerosene
  The consumer gains substitution

surplus amounted to 2.3 kgs of coal briquette per litre of kerosene.

- Coal briquette versus IDO
  The consumer gains substitution surplus of 0.5 kg of coal briquette per litre of IDO.
- Coal briquette versus the imported cokes.
  The domestic briquetted coke could compete with the imported cokes if it is used in foundry industry (iron casting).

The current status of development profile of Indonesian coal value added processing R&D can be seen on Enclosure A.

3). Impact of implementation of coal based product diversification on macroeconomic
The domestic consumption of energy in Indonesia :

- in 2005 it was 864.60 million BOE (Biomass of 270.04 million BOE);
- and of 1,081.43 million BOE (Biomass of 288.44 million BOE) in 2010.

The total oil fuel consumption in 2005 was around 338.52 million BOE, and in 2010 it was of about 363.52 million BOE approximately. The total commercial energy was consumed by the four main sectors, i.e. transportation, industry, household and commercial, amounted to 792.99 million BOE in 2010. (Anonymous j, Center for Data and Information on Energy and Mineral Resources, 2011). Besides oil fuel, the sectors of industry, commercial and households also consume gas, coal and other kinds of energy sources.

In the transportation sector, the total consumed oil fuel is about 264.80 million BOE, and in the industrial sector is of around 55.09 million BOE, so that the total consumed oil fuel in these two sectors of around 319.89 million BOE that could be substituted by CSO valued US$ 25.59 billion a year. More specific potential substitution of heavy diesel oil (HSD oil) into CWM, the HSD consumed by the industrial sector of around 42.76 million BOE. Then, the total savings would be US$ 3.42 billion as CWM substitution benefit in this industrial sector.

If the national total consumption of fuel oil in 2010 was about 363.52 million BOE, then it would save US$ 29.08 billion per year (the price of oil fuel of US$ 80/bbl), if it is substituted by CSO. And this requirements should be carried out into several stages of implementation based on the strong government policy.

4). The price trend of coal.
Actually within the last 15 years, the world price trend of steam coal tended to increase with 20.93% average growth rate per year from US$ 30.07/ton in 1996 up to US$ 129.59/ton in 2011 (Figure 7). This trend projection up to the year of 2025 would be around US$ 240-260/ton. It is obvious that the price of crude oil would also increase significantly. Of course, the price trend of coal would affect the price of synoil as well as the price of producer gas or other products of coal diversification in lieu with the price trend of crude oil and natural gas.

5). The multiplying effects on the regional development.
The economic multipliers and the backward and forward linkages of the CMS (coal mining sector), OGMS (oil & gas mining sector) and ORS (refinery sector), 2001 and 2011 can be summarized as follows (Table 4).

Based on the above results it can be indicated that:

- The more downstream the sector, the higher the multiplier and the stronger the backward and forward linkages will be.
- In 2001 and on the multiplying effects of the coal liquefaction to the regional development will be positively greater and greater.

b. Environmental aspects
The followings are several environmental tests on the ambient and emission air.

1). Quality of flue gas of CFPP in Indonesia.
For example, the content of $SO_2$ in flue gas of the CFPP Suralaya in Indonesia is of 600-700mg/m$^3$ by using coal with 0.4% sulfur content of coal (The Environmental Quality Standard: 750 mg/m$^3$, Regulation Men LH No 21/2008), but it is of 1400-

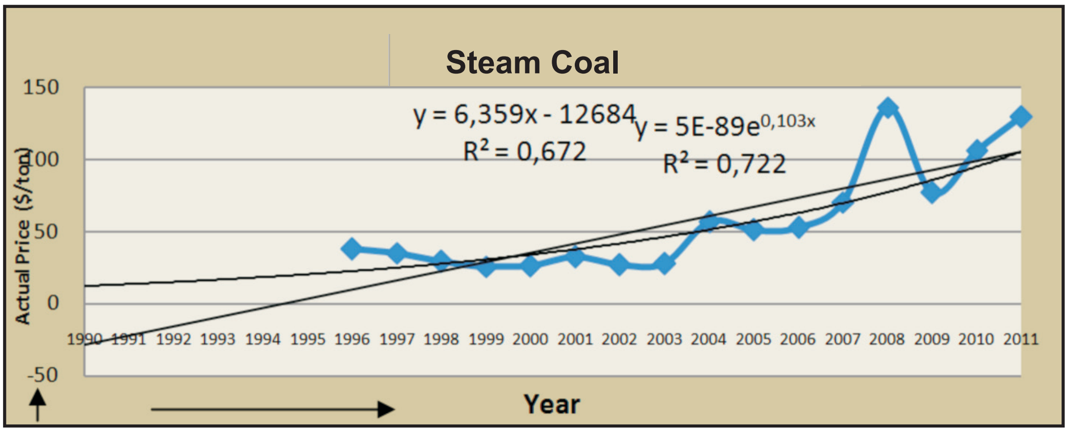



**Figure 7. Graph of world coal price trend, 1996-2011**

Table 4. The multiplying and linkages effects of the regional development due to the development effort of coal liquefaction

| | CMS (Coal mining) | OGMS (Oli & gas mining) | ORS (Refinery) |
|---|---|---|---|
| A. 2001: | | | |
| 1. The multipliers:*) | | | |
| a. Employment | 1,12 | 2,21 | 2,10 |
| b. Investment | 1,09 | 1,17 | 2,92 |
| c. Added value | 1,13 | 1,07 | 3,68 |
| 2. The linkages:**) | | | |
| a. Backward | 0,78 | 0,74 | 1,23 |
| b. Forward | 1,00 | 1,71 | 1,58 |
| B. 2011: | | | |
| 1. The multipliers:*) | | | |
| a. Employment | 1,08 | 3,67 | 5,89 |
| b. Investment | 1,11 | 1,13 | 3,41 |
| c. Added value | 1,22 | 1,05 | 2,50 |
| 2. The linkages:**) | | | |
| a. Backward | 0,84 | 0,75 | 1,20 |
| b. Forward | 0,80 | 1,40 | 1,36 |

Note: *) It is computed by using formulas of economic multipliers and the inversed Leontief matrix of the 1994 regional Input-Output table of South Sumatera province then updated to the year of 2001 and 2011.

**) It is computed by using the formulas of backward and forward linkages and the inversed Leontief matrix of the same regional I-O table of South Sumatera province

Source: Soelistijo et. al, 2002.

1500 mg/m$^3$ $SO_2$ at Tanjung Jati power plant (Central Java) by using 0.9% sulfur content of coal, even though they has installed FGD (Anonymous m, 2012). The Environmental Quality Standard based on Minister of Environment Regulation No. 21/2008 is that Particulate matter 100 mg/m$^3$, $SO_2$ 750 mg/m$^3$, NOx as $NO_2$ 750 mg/m$^3$, and Opacity of 20%.

2). Quality of ambient air, environmental air and emission air of diesel power plant
The quality of ambient air is much lower than ambient air quality standard (the qua lity standard of $NO_2$ 150 µg/Nm$^3$, $SO_2$ 365 µg/Nm$^3$, SO2 10,000 µg/Nm$^3$, particulates 230 µg/Nm$^3$, the GOI). The concentration of each pollutant is still far below the working environmental air standard quality decided by the Ministry of Manpower and Transmigration, 1997). The air quality of off-take emission gas of diesel machine using dual fuel is still lower than the quality standard of air quality of unmoved source emission (Anonymous h, 1995; Suprapto et. al, 2009).

3). Waste gases and particulates resulted from briquette combustion
One of many coal utilizations as fuel is the use of coal briquette that is expected to be able to meet household and small industry demand for fuel. The negative impact caused by utilizing briquette is air pollution due to the emission of gas removal resulted from its burning in the forms of fly ashes as small particles and toxic gases. Research on gases removal from burning of coal briquette has been carried out, in particular gases of COx, NOx, and SOx. The samples used are of Palimanan West Java (MCTRDC Pilot Plant Coal Center Laboratory) waste wood briquette (BS), waste agriculture briquette (BB), and Tanjung Enim coal briquette (BT) and Lampung coal briquette (BL), where charcoal (AK) is used as a standard of comparison. The research results show that the disposal gas emission of the five types of fuel have similar pattern, i.e. within the first twenty minutes at the temperature of 150-600°C the gas emission are still below the EQS (300 mg/m$^3$). The effort of controlling air pollution could be carried out towards preserving the environmental quality through, among others, planting several types of plants that could be able to absorb the polluter gases, and the efforts of REDD that should be necessarily encouraged as far as possible (Damayanti and Soelistijo, 2011).

The domestic consumption of primary energy in Indonesia :

- in 2005 was 864.60 million BOE or about 1,081.43 million BOE (including biomass of 288.44 million BOE) in 2010. The total fossil fuel consumption in 2005 was around 792.99 million BOE.

The emission of carbon would be 144.7 million tons per annum or equal to 530.63 million tons of $CO_2$.

- 61.02 million tons of $CO_2$ emissions came from coal combustion in power generations, cement, and biomass combustion from small industries and rural households.
- The biomass fuel consumption of small industry and rural households might be substituted into briquette (of coal and biomass or mixed).

Indonesia constitutes an archipelago with widespread tropical forest and vegetation.

- The total area covers 5.2 million km$^2$ ( consisted of 1.9 million km$^2$ of land and 3.3 million km$^2$ of ocean or sea).
- The forest area is estimated to be about 119.7 million Ha.
- On Java island (the densest population in Indonesia) the forest area is of about 3.01 million Ha which is less than 30% of the Java land area (the required minimum percentage area of forest).

## CONCLUSION AND RECOMMENDATIONS

### Conclusions

The effort of substitution of coal and its diversification product into oil fuel would result substantial economic gain besides certain level of regional economic benefit to overcome the declining less and less reserves of domestic oil faced by the Indonesian people within the coming few years. If the national total consumption of fuel oil in 2010 was about 363.52 million BOE, then it would save US$ 29.08 billion per year, if it was substituted by CSO.

The producer gas – IDO in the diesel power plant through dual fuel system would save US$ 3.34 billion in 2011 if all diesel power plant in Indonesia using dual fuel system (Anonymous k, 2011). Of course utilization of coal as direct fuel in the coal fired power plant has gained billion dollar since several ten years ago, which has consumed around 40 million tons of coal per year for 12,050 MWs of power plant, besides 6 million tons of coal for cement industry and another 14 million tons of coal for other industries. And this trend of coal demand should be supported by the strong government policy.

Upgrading technology, either UBC process, carbon-tech drying, HWD or SD provides the ability to increase calorific value of low rank coal through reduction the moisture content. The upgraded coal has prominent stability in water content, so it could be transported for long distance such as for exports.

The efforts of coal utilization through direct and diversification ones affects employment creation and increasing income for the people, so these efforts should be encouraged within the coming years.

### Recommendations

It is necessary to continue in the cases of:
- The study of locating diesel power plant as close as possible with the location of coal stock piling to facilitate the development of coal gasifier combined with the diesel power plant.

- Acceleration of applied technology investigation of bio-energy utilization facing the post coal era as the end of fossil fuel era to look the sustainable future of Indonesia energy path.

- It is required to build the new energy policy to accelerate the coal liquefaction program due to the decreasing less and less reserves of the domestic oil within this decade.

- Besides the efforts of utilization domestic gas potentials such as coal bed methane, shale gas and the remainder of natural gas coal gasification programme should be well encouraged and enlarged.

- Application of environmental technology and/ or environmental friendly coal diversification technology should be a priority to overcome the negative effects of the resulted solid, liquid and gaseous (COx, NOx, SOx, and others) and pollutants that may contain metals (copper, lead, zinc, mercury, and trace elements etc) that may endanger the human health and the environment. Various efforts of increasing the carrying capacity of the environment are required to fase the population pressure. It is very difficult to reduce population pressure growth rate, with the various negative impacts toward the carrying capacity of the nature.

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## ENCLOSURE

Enclosure A. The current status of development profile of Indonesian coal added value processing R&D

| Stages | Types of process | | | | |
|---|---|---|---|---|---|
| | Coking | Briquetting/ Bio-coal making | Upgrading Brown Coal (UBC) | Gasification | Liquefaction |
| 1. Investigation | Pilot plant | Pilot plant 10,000 tons per day (tpd) | Pilot plant 5 tpd | Pilot plant Tea leaves drying (50 kgs per hour) | - Laboratory scale (*tek*MIRA)<br>- NEDO, Bench Scale Unit, 0.1 ton/bench |
| 2. Commercial | Capacity 3,000 tpd. Investment IDR 10 billion | 1 liter of kerosene = 1.4 kgs of briquette | Capacity: 5,000 tpd. Investment US$ 91 million | Capacity: 60 kgs coal/hour. Investment IDR200 million | - NEDO, Cap. 3000, 6000, 12000 bbl/day. CSO US$ 22-34/bbl. |
| 3. Economic prospect | - Price US$ 4000/kg.<br>- Competitive with ex imported coke (IDR 4500/kg) | Substitution surplus:<br>- 2.3 kg briquette per litre of kerosene.<br>- 0.5 kg briquette per litre IDO. | | - Lurgi.<br>- Winkler.<br>- Koppers-Totzek. (US$ 4.75/MMBTU).<br>- Tigar (US$ 3.5/MMBTU).<br>- tekMIRA type: (Tea leaves drying, cost savings of 40-50 %). | - Price of crude oil (CO) US$ 80-100/bbl.<br>- Substitution surplus 0.27 bbl CSO/bbl CO. |