# PROSPECT OF COAL LIQUEFACTION IN INDONESIA

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**Abstract**

*With the current known oil reserves of about 11 billion barrel and annual production of approximately 500 million barrel, the country's oil reserves will be depleted by 2010, and Indonesia would have become net oil importer if no major oil fields be found somewhere in the archipelago. Under such circumtances the development of new sources of liquid fuel becomes a must, and coal liquefaction can be one possible solution for the future energy problem in Indonesia, particularly in the transportation sector due to the availability of coal in huge amount.*
*This paper present the prospect of coal liquefaction in Indonesia and look at the possibility of integrating the process with HTR as a heat supplier. Evaluation of liquidability of several low grade Indonesian coals will also be presented. Coal from South Banko-Tanjung Enim is found to be one of the most suitable coal for liquefaction. Several studies show that an advanced coal liquefaction technology recently developed has the potential to reduce not only the environmental impact but also the production cost. The price of oil produced in the year 2000 is expected to reach US $ 17.5~19.2/barrel and this will compete with the current oil price.*
*Not much conclusion can be drawn from the idea of integrating HTR with coal liquefaction plant due to limited information available.*

## I. INTRODUCTION

A key and continuing thrust of the national energy strategy is to optimize the use of non-exportable energy and therefore to conserve exportable surplus of crude oil and thereby to slow down the pace of Indonesia's transition to net oil importer status (Ramlan, 1994).

With the current known oil reserves (11 billion barrels) and annual production of about 500 million barrel oil (Ramlan, 1994), the country's oil reserves will be depleted in the middle of PJP-II's period, and that time (2010) Indonesia would have become net oil importer if no major oil fields be found somewhere in the archipelago. Under such circumtances, the development of new sources of liquid fuel becomes a must.

Coal, on the other hand, offers the potential for stable supply and therefore relatively stable price. At present, its reserves in Indonesia is estimated to reach 36.6 billion tons. Unfortunately, more than 70 % of that coal reserves are mainly in the form of low rank coal or lignite. The unfavourable nature of this low quality coal makes it difficult to be stored and transported, for example it has so many holes and consists of considerable water; when it is exposed to air, there is a strong possibility of self-igniting. Besides, the utilization technology of this low grade coal is still limited at the moment.

To secure the future of energy supply while preserving the oil reserves, the country must find an alternative energy by utilizing such huge amount of low quality coal. Regrettable, modern life relies very much on the use of oil and other liquid fuels particularly in the transportation sector that coal is not suitable. Therefore, coal must be converted into oil through a process known as coal liquefaction. The process produces synfuel for transportation such as gas oil, gasoline and kerosine.

This paper presents the prospect of coal liquefaction technology in Indonesia. First, it discusses what coal liquefaction process is and its latest development status, followed by brief overview of coal liquefaction research in Indonesia and results from evaluation of liquidability of several low rank Indonesian coals conducted at LSDE-BPPT and Takasago Laboratory, Japan. Finally, the economic evaluation of a coal liquefaction plant is presented. Advanced brown coal liquefaction technology is used more in this analysis due to the availability of the data (Source of data : NBCL, Japan).

## II. WHAT IS COAL LIQUEFACTION?

Coal liquefaction can be divided into two processes, i.e. direct and indirect coal liquefaction. *Indirect Coal Liquefaction* is the production of hydrocarbons from carbon monoxide and hydrogen in the presence of Fischer-Tropsch catalyst (Lee, 1979). The process was originally develop by Fischer and his partners. Full scale commercial plant built in 1950s in South Africa by Sasol is the only commercial liquefaction plant ever built in the world today. Despite it is very expensive in terms of thermal effisiency, the process itself is quite flexible. By adjusting the composition of catalyst, hydrogen/carbon ratio and operating conditions, a wide variety of products can be obtained. Moreover, other products such as methanol and acetone can also be produced by using different catalysts.

*Direct coal liquefaction* is a process which decomposes high molecular structured coal into lower molecular structured oil in the presence of hydrogen solvent and catalyst at a certain operating condition. Clearly, by blending coal, as a hydrocarbon compound like petroleum (but exists in solid form because of its greater molecular weight and lower hydrogen to carbon ratio), with catalyst and a hydrogen donor solvent at a very high temperature and pressure, the coal's polymer chains can be broken down, causing it to liquefy into an artifial petroleum. Direct Coal liquefaction is considered to take place into two consecutive steps : conversion to a soluble form (dissolution or depolymerization), and reduction in molecular weight and removal of heteroatoms, which is often called as up grading process (Fernandez et.al., 1995)

Numerous coal liquefaction projects are currently under development, and most of them are using direct coal liquefaction process as shown in the following schematic diagram (Figure 1). The energy efficiency of several coal liquefaction processes, which varies between 57 - 71%, is presented in the table 1. EDS, SRC-II and ITSL of USA use bituminous and sub-bituminous coals, while *Advance Brown Coal Liquefaction* process (BCL) uses low grade coal or lignite as a feedstock. Research on advanced BCL process using Indonesian low quality coal from Tajung Enim (South Banko) conducted by NBCL-Takasago Laboratory shows that its energy efficiency is higher than Victorian coal.

The study of advanced BCL process was commenced in 1993 as an improvement of the original concept design of 50 ton/day pilot plant built in Morwell, Victoria-Australia, The Victorian Brown Coal Liquefaction was intended to obtain technical data needed for scale-up to a commercial plant. Modification was made from the following points of view : less energy consumption, less construction cost, higher oil yield and more up graded products. The advantages offered by advanced BCL process compared with the original conceptual design are presented in table 2, while the difference between the two processes are shown in Figure 2 and 3.

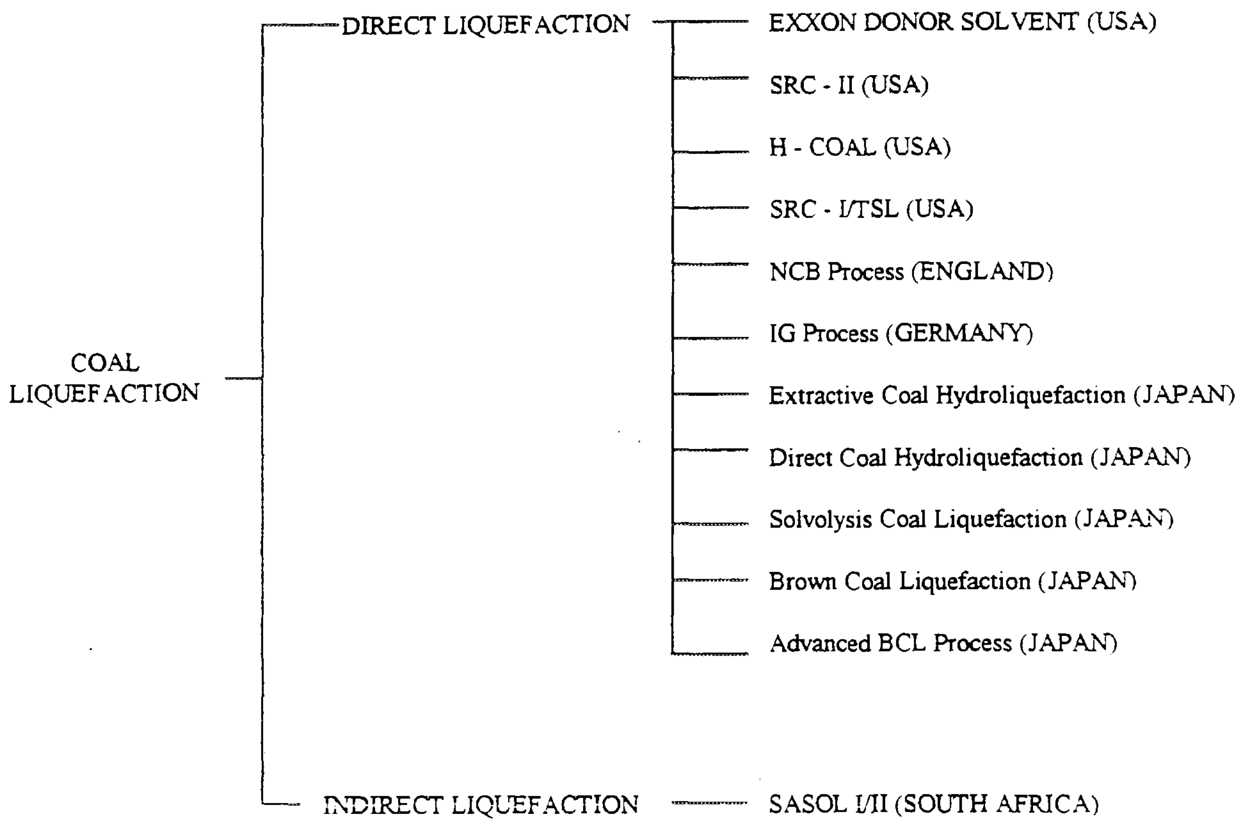


**Figure 1. Coal liquefaction projects in the world**

**TABLE 1. ENERGY EFFICIENCY OF COAL LIQUEFACTION PROCESS**

| | |
|---|---|
| Original Conceptual Design | 57.3% |
| Advanced BCL Vic. Coal with Hydrotreator | 60.4% |
| Advanced BCL Vic. Coal | 66.9% |
| Advanced BCL Ind. Coal with Hydrotreator | 65.8% |
| Advanced BCL Ind. Coal | 70.2% |

## Other Processes

| | | |
|---|---|---|
| EDS | Sub-Bituminous Coal | 57~58.5% |
| SRC-II | Bituminous Coal | 66~71.0% |
| CC-ITSL | Bituminous Coal | 67.9% |

**TABLE 2. ADVANCED BCL PROCESS OFFERS SIGNIFICANT ADVANTAGES**

1. Simplified Liquefaction Process Makes High Efficiency With Low Cost.
   Primary Hydrogenation With Half Scale Deashing Unit.
   Inline Vapour Phase Hydrotreator Instead Of Secondary Hydrogenation Unit.
2. Low S/C Ratio & High Plant Efficiency By "Dual Peaks Solvent System".
3. Inline Hydrotreator To Improve Product Quality.
4. DAO (De-Ashed CLB) Recycle Operation Lightens Erosion Troubles.
5. High Reactive Iron Catalyst To Improve Oil Yield & Operational Reliability.
6. Introduction Of De-Carboxylation In Slurry Phase To Reduce Scale Formation.
7. No Preheater Operation Required During Normal Operation.
8. Multiple Reaction Temperature Profiles Would Change Yield Structures.
9. Hot And High Pressure Bottom Recycle.
10. Slurry Preparation Without Ball Mills.
11. CLB Direct Feed To Deashing Unit.
12. Max. Power Recovery From Gas & Liquid
13. $C_3$, $C_4$ Recovery From Plant Off Gases.
14. Optimization Of Plant Fuel Systems.

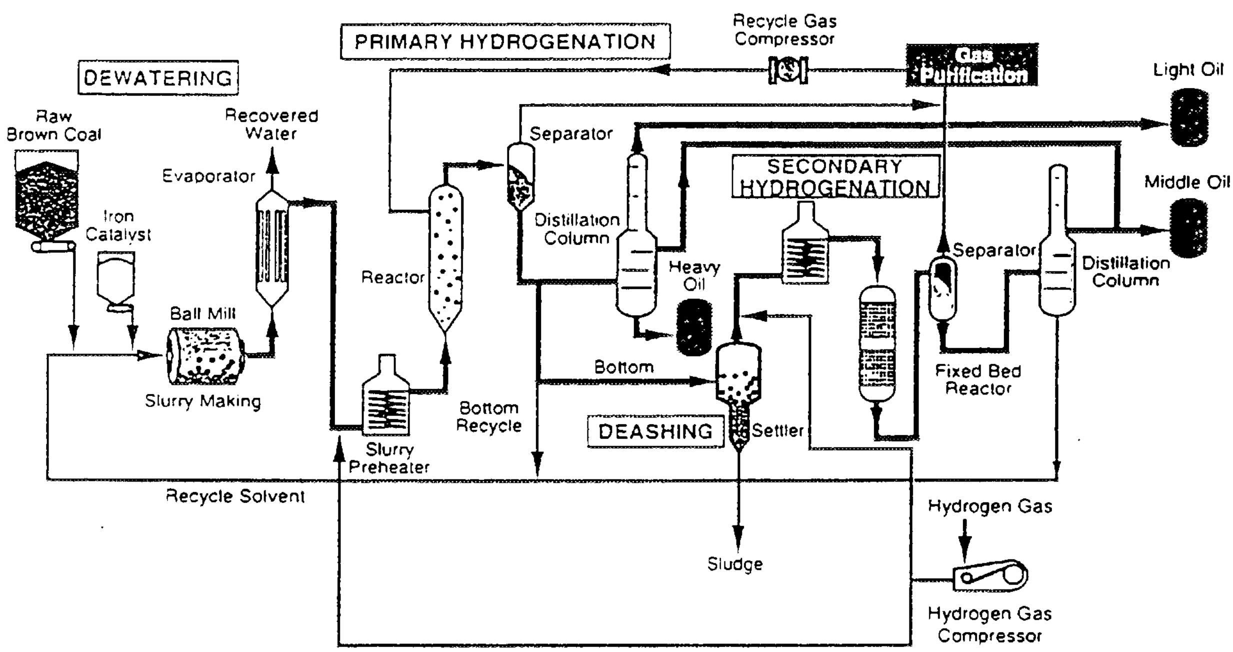


**Figure 2 : Brown Coal Liquefaction Plant**

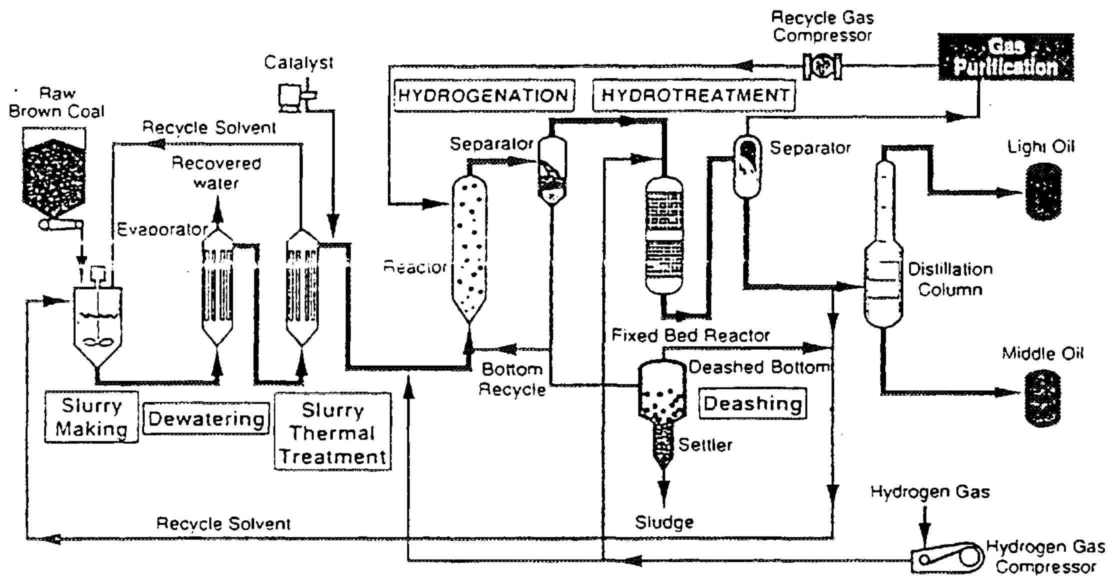


**Figure 3 : Advanced Brown Coal Liquefaction Plant**

## III. OVERVIEW OF COAL LIQUEFACTION RESEARCH IN INDONESIA

Coal liquefaction research has been carried on in Indonesia since early 1990s. at MTRDC (Mineral Technology Research and Development Centre-Bandung) and ITB (Bandung Institute of Technology using small scale reactor (autoclave). In 1993, BPP Teknologi, in cooperation with NEDO-Japan, commenced Indonesian brown coal Liquefaction colaboration study to investigate the liquidability of Indonesian coals and the economic of the process.

Coal samples from five different mining areas (Cerenti, Adaro, Pasir. Berau and South Banko) have been tested at NBCL-Takasago Laboratory, Japan and at LSDE - BPPT, Puspiptek, Serpong. The laboratory study using 0.5L autoclave, shown that lignite from South Banko in Tanjung Enim, Palembang, South Sumatra has the highest coversion effisiency, produces approximately 70% of liquid fuel. As a comparasion, 1 ton of Victorian raw coal (with 60% moisture) produces only about 1 barrel of liquid fuel, while each ton of raw South Banko coal (with about 35 % moisture) can produce approximately 3 barrel of oil. Figures 4 and 5 show the comparison of hydrogen, carbon. oxygen and sulfur contents of Indonesian coals and coal from Yallourn (Victorian), and the liquefaction results of those coals using 0.5 liter autoclave.

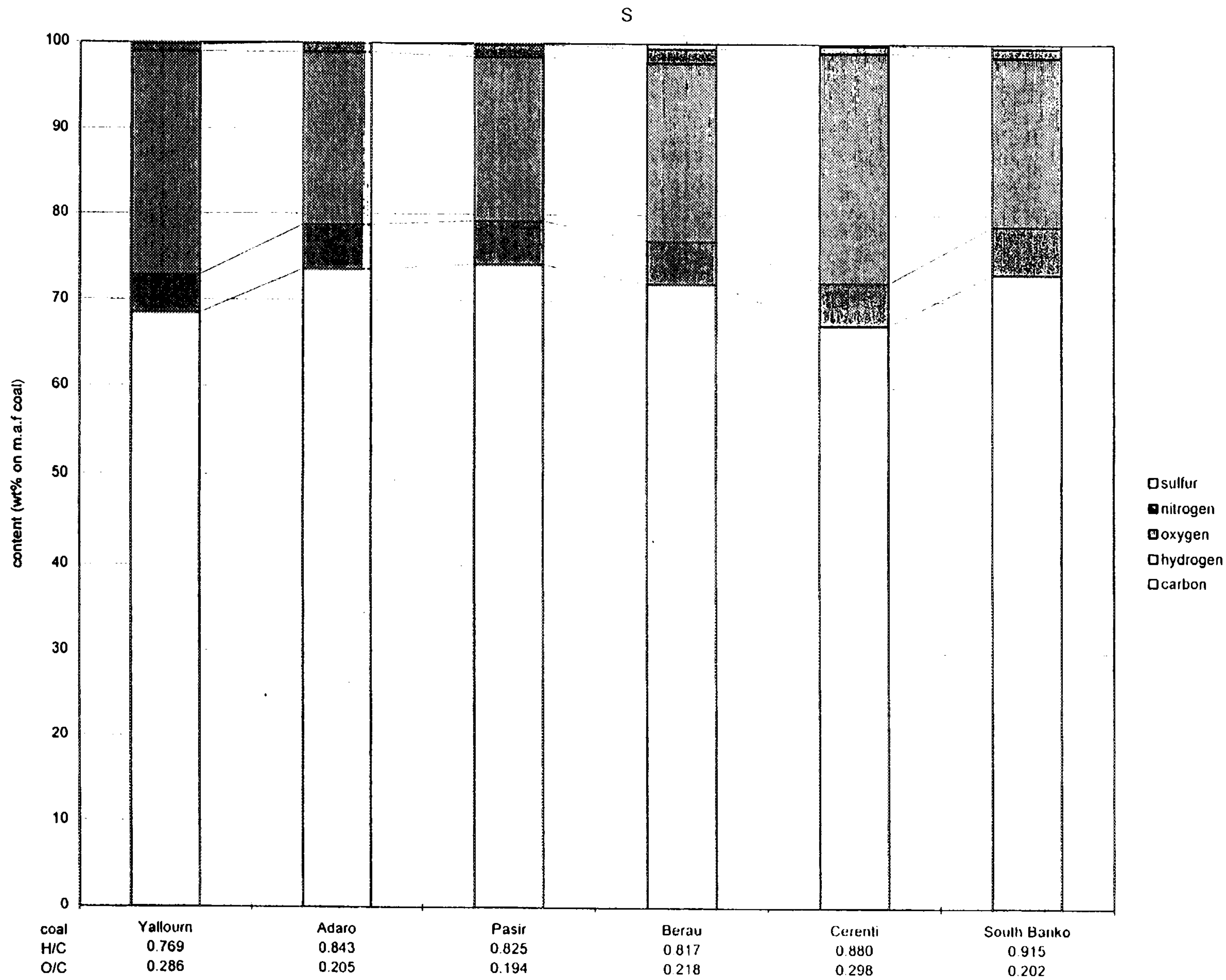


**Figure 4. Comparison of the contents of component**

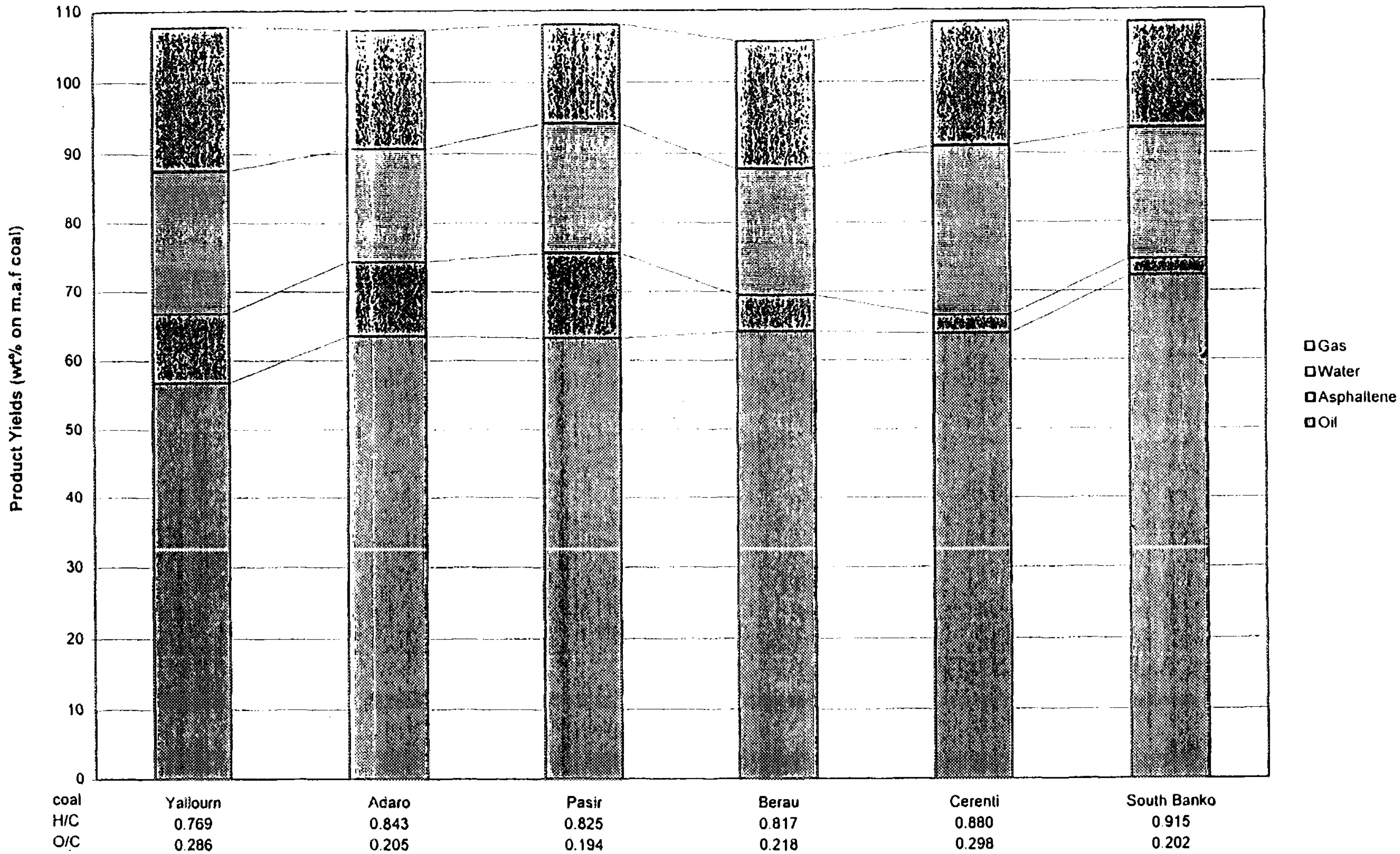


**Figure 5. Comparison of the liquefaction product yields at 450°C/2~24 Mpa**

Figure 6 and 7 show the concept of coal liquefaction process and proceeding of AC experiment, respectively. First, coal is dried and pulverized, and then mixed with pulverized iron ore as a catalyst and solvent hydrogen. The slurry mixture is heated and pressurized at about 430-450 °C and 15-25 Mpa performing liquefaction. Second, before it is destillated, liquified coal is hydrogenated (up-graded) in the present of catalyst. To produce marketable products liquefied coal needs to be rifined.

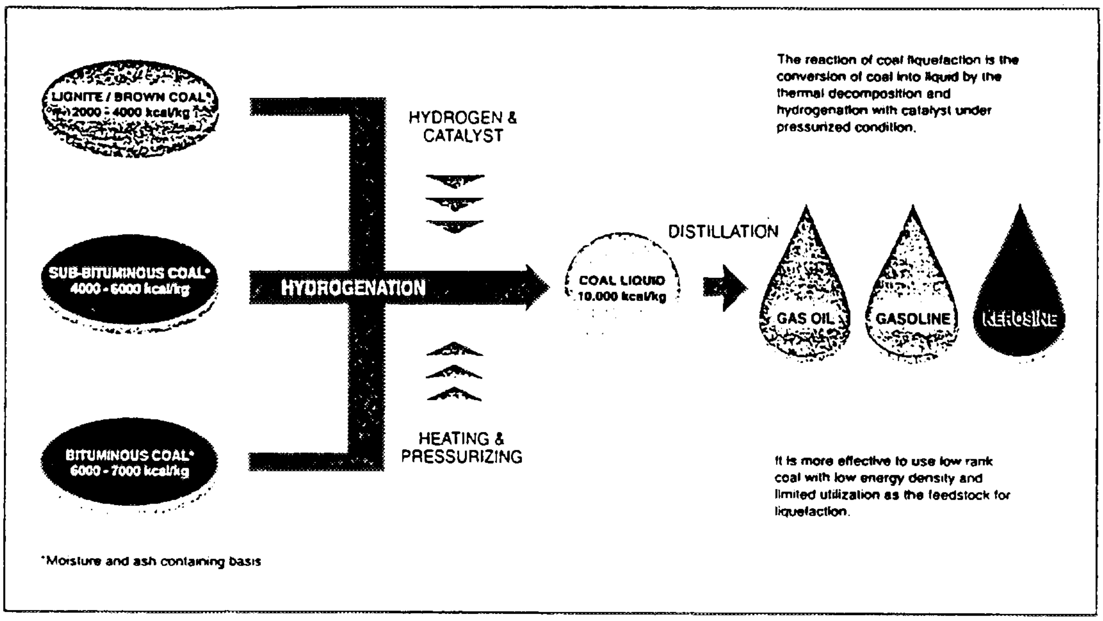


Figure 6 : Concept of Coal Liquefaction Process

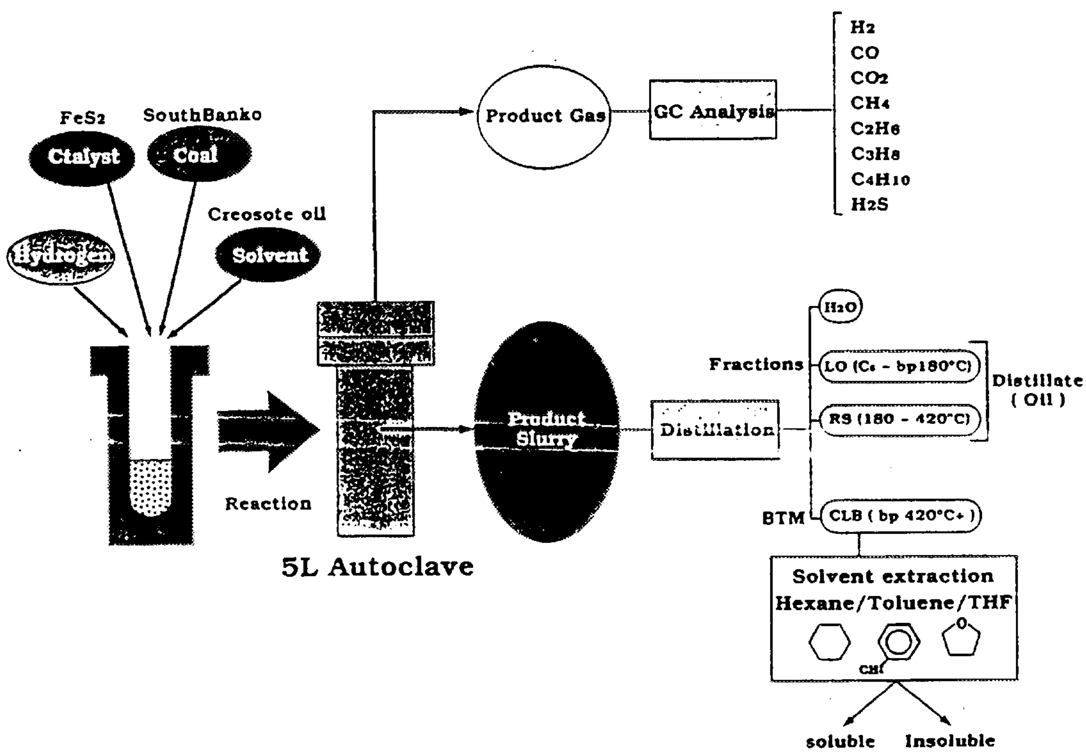


Figure 7 : Proceeding of Autoclave (AC) Experiment

The phase one of the research cooperation between BPPT and NEDO is planned to be completed by March 1996. At the moment about 10 tons coal sample from South Banko-Tanjung Enim is being tested in Takasago using a 1 ton BSU (continous) coal liquefaction. One Indonesian Engineer is working at the Laboratory together with the NBCL's experts to carry out the liquefaction research of South Banko coal which is expected to finish by medio 1996. Following this, a preliminary feasibility study will be conducted to determine the economy feasibility of brown coal liquefaction in Indonesia. Detail feasibility study is planned to be carried out for three years starting from 1996 to 1999.

## IV ECONOMIC EVALUATION OF A COAL LIQUEFACTION PLANT

Study conducted by Gray and Tomlinson (1988) showed that the cost of hydrotreated product (oil) from Illinois coal for ITSL and H-coal plants or EDS plant are more than US \$ 40/barrel in 1986. This price of course, are too expensive and can not compete with the current price of crude oil which is vary between \$ 16 to \$18/barrel.

As previously mentioned, modification for further improvement was made in Brown Coal Liquefaction, and it is called with *Advanced BCL* process. Some significant process improvements can significantly reduce investment cost and operating cost. By adoption of the dual peaks solvent, for example, solvent to coal ratio will be reduced from 2.5 to 1.8. Moreover, as light fraction corresponding with S/C= 0.74 would move to vapor phase in the reactor, actual slurry quantity decreases from 337 $m^3/h$ in the conceptual design case to 169 $m^3/h$ which means significant improvement of space efficiency on reactor section. This will affect not only the reactor but also slurry handling system, and reduce the number of slurry feed pumps to about 50%. As a result, the investment cost as well as operating cost will be reduced significantly.

Other process improvements have also been made in the Advanced Brown Coal Liquefaction. They are :

1. Mixing the pulverized coal directly with the recycle solvent in slurry mixing tank can eliminate the ball mill plants.

2. The reactor effluent slurry depressurized to 5 Mpa by the single pressure letdown valve contains a very small amount of light fraction which allows direct feed of CLB *(Coal Liquid Bottom)* to the deashing unit operated at 3.5 Mpa. This will eliminate the secondary pressure letdown valve system and CLB separation under the full vacuum.

3. At without hydrotreating case, adding a gas separation plant allows a recovery surplus of C3 and C4 of about 4.2% on mafc in total, resulting an improvement of product yields.

4. No CLB production and small quatity of waste sludge from the advanced process leads to the elimination of the waste sludge incinerator. The waste sludge can be incinerated in the coal fired boiler.

Those improvements lead to the substantial reduction in all costs of the plant. Results of the economic analysis, which was carried out using the discounted cash flow rate of return, shows in the case that design and construction for a commercial plant would commence in 1996 and begin to sell product from 2000, the product oil price (with hydrotreating case) would be US $19.2/barrel (no infration), a 25% decrease compared with US $ 25.5/barrel (no infration) for the conceptual design case. For without hydrotreating case, product oil price would also again be reduced to US $ 17.5/barrel, a 31% decrease. The price of oil produced by advanced coal liquefaction process could be competitive with these forecasts even with such a very low forecast as US $ 15/barrel in 1994 and 1.5% per year escalation.

Evaluation of the advanced coal liquefaction process was carried out in the scale of 30,000 ton maf coal/day that consists of 5 parallel trains with the capacity of 6,000 ton/day each train. The plant location is sited near a coal mining area in the Latrobe Valley Victoria. The production capacity of this plant is approximately 124,000 barrel/day (with hydrotreator) to 132,000 barrel/day (without hydrotreator). The construction cost of the commercial plant is based on the conceptual design for 6,000 ton/day demonstration plant with some modification.

## V GAS EMISSIONS

Table 3 shows the emission of Carbon Dioxide released by several Coal Liquefaction processes and Advanced Brown Coal Liquefaction has the lowest emission, although it uses lower rank coal compared with other process such as ESD Direct Liquefaction and F-T Synthetic Indirect Liquefaction..

## VI INTEGRATED PROCESS

One possibility of supplying energy required for coal liquefaction process is by having an integrated process which combines *High Temperature Reactor* (HTR) with the the coal liquefaction plant. The role of *High Temperature Reactor* (HTR) is to supply heat for coal liquefaction process. The heat produced in the reactor core is transferred by helium gas as coolant circulated gas. The outlet gas from HTR has temperature more than 900 °C, promise a wide application in process. This energy can be used to provide heat required at the dewatering process, thermal treatment unit to increase the slurry temperature up to 350-420 °C before is fed to the coal liquefaction reactor, and distillation

**TABLE 3. GREEN HOUSE GAS EMISSIONS**

| | |
|---|---|
| **Original Conceptual Design** | **21.5g-C/Mj-product** |
| **Advanced BCL Vic. Coal with Hydrotreator** | **20.3g-C/Mj-product** |
| **Advanced BCL Vic. Coal** | **17.2g-C/Mj-product** |
| **Advanced BCL Ind. Coal with Hydrotreator** | **14.1g-C/Mj-product** |
| **Advanced BCL Ind. Coal** | **12.7g-C/Mj-product** |

**Other Processes (Wandoan Coal)**

| | |
|---|---|
| **EDS Direct Liquefaction** | **26.6g-C/Mj-product** |
| **Methanol Indirect Liquefaction** | **26.3g-C/Mj-product** |
| **F-T Synthetic Indirect Liquefaction** | **41.0g-C/Mj-product** |
| **MTG Gasoline Indirect Liquefaction** | **35.8g-C/Mj-product** |

column. Theoritically, this concept can possibly be done, but the heat waste generated from HTR must be well utilized for other purposes, for example, to generate electricity or provide energy for other process. Unless the energy supplied by HTR is effiently utilized, this approach may not be attractive. Unfortunately, there is not much information available regarding the integration of HTR and coal liquefaction plant. Futher detail study is required.

## VII CONCLUSION

1. Coal liquefaction can be one possible solution for the future energy problem in Indonesia, particularly in the transportation sector.

2. Coal from South Banko-Tanjung Enim is found to be one of the most suitable coal for coal liquefaction, in fact, it offers the highest energy efficiency.

3. Advanced brown coal liquefaction has the potential not only to reduce the environmental impact but also reduce the production cost.

4. The oil produced from Advanced BCL process in the year 2000 would be US $ 17.5~19.2/barrel. This will be competitive against the current oil price.

5. Not much conclusion can be drawn from the idea of integrating HTR with coal liquefaction plantdue to limited information available.

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