

Product Competitiveness of Upgrading Brown Coal (UBC) Process in Indonesia

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Abstract— The utilization of coal in Indonesia is in a running of improvement to become the biggest energy source. In 2025, 30% of total energy used is targeted as stated in Indonesian Government Regulation No. 79 of 2016. In Indonesia, the potential coal is mostly found in low and moderate calorific coal, it is classified as brown coal. Commonly, brown coal has high moisture content. Upgrading Brown Coal (UBC) process is a method for reducing the moisture content of brown coal by up to 80%. This study provides an overview of the UBC product competitiveness compared with brown coal. It will generate some technical recommendations on the current energy policies. Business as Usual (BAU) scenario and UBC product scenario were applied to show the difference in the amount of coal needed to generate electricity with the same capacity and the total of green house gas emission potential (GEP). The calculation was performed using the LEAP program (Long-range Energy Alternative Planning system). The use of UBC product potentially reduced the feed consumption by 50% compared to usual brown coal. Furthermore, the GEP calculated between the two scenarios was 1.141 billion kg CO₂-eq/year as net saving. UBC process can be developed to improve the quality of brown coal so that the UBC product will be much more competitive.

Keywords— Upgrading Brown Coal (UBC); UBC product competitiveness; green house gas emission; electricity generation; energy policy

I. INTRODUCTION

The International Energy Agency (IEA) estimates that nearly 80% of the world's energy needs up to 2035 which is fulfilled by fossil fuels. Regarding world primary energy demand in 2035 as presented in Table 1, coal will replace the position of oil that is expected to remain the largest energy source.

In Indonesia, coal is expected to replace oil as a major energy source in the target set out in the energy mix of the Indonesian Government Regulation No. 79 of 2014 on National Energy Policy [1]. This policy is fully supported by the total coal resources in Indonesia until 2015 stood at 126.61 billion tons with total coal reserves of 32.26 billion tons [2]. Using coal as solid fuel and increases in the state income from the coal sector has yet to reach the maximum point because Indonesian coal is low-quality coal, called brown coal. In using of brown coal as an energy source for electricity generation, upgrading brown coal (UBC) as one of the clean coal technologies that are being widely applied

in developing countries in order to increase the efficiency of combustion processes in the power plant sector.

TABLE I
WORLD PRIMARY ENERGY DEMAND & ENERGY RELATED CO₂ EMISSIONS (MTOE) [3]

			Current Policies	
	2000	2010	2020	2035
Total	10,097	12,730	15,332	18,676
Coal	2,378	3,474	4,417	5,523
Oil	3,659	4,113	4,542	5,053
Gas	2,073	2,740	3,341	4,380
Nuclear	679	719	886	1,019
Hydro	226	295	377	460
Bioenergy	1,027	1,277	1,504	1,741
Other Renewable	60	112	265	501
CO₂ emissions (Gt)	23.70	30.20	36.30	44.10

Brown coal has high moisture content while the UBC process can reduce the moisture content of brown coal by up to 80%. The UBC process conducted over several principles,

namely to increase quality coal with the following standards [4]:

- Reduce moisture of low-rank coal/brown coal up to 80%, by moisture reduction from 25- 50% to <10%
- Increase CV of low rank coal / brown coal (< 5,000 kcal/kg) into a UBC product (Fig. 1) similar to high rank coal / hard coal (>6,000 kcal/kg) based on slurry dewatering process

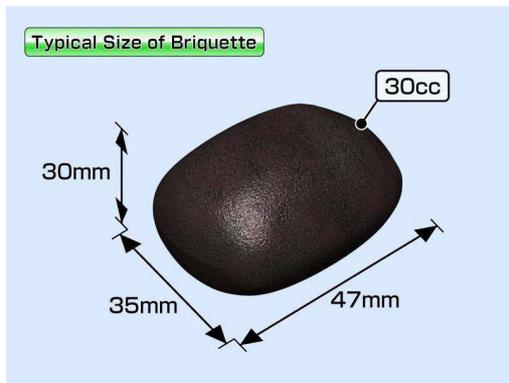


Fig. 1 UBC product

Having population growth of 1.3% and annual economic of 6.1%, respectively, the need for electricity is estimated to grow around 9.2% per year [5]. Low efficiency of brown coal used in boilers means not only to reduce economic values of brown coal but also to increase the impact on its overall behavior on the thermal efficiency and so on the amount of CO₂ and other pollutants, such as emissions of particulates, SO₂, NO_x and mercury produced per MW of power [6]. Electricity generation using boiler can be used as a standard to see UBC competitiveness when compared to brown coal as usual. Besides being able to meet the needs for supplying of environmentally friendly domestic energy sources, UBC also can increase the added value of brown coal itself so it can be fully utilized for domestic needs and able to export at a higher price.

In terms of economic performance, annual cash flow (ACF) and net present value (NPV) were positive after the production process. The internal rate of return (IRR) is 9.36 % and the payback period (PBP) is 9 years of 20 years of lifetime project. In summary, the analysis showed that the UBC plant is most likely to be feasible [7].

This study provides an overview of the opportunities and advantages in the implementation of UBC projections based on greenhouse gas emission potential and its product competitiveness and makes recommendations in the field of energy policy.

II. MATERIAL AND METHOD

PT. Bukit Asam in Tanjung Enim is one of the largest company which produce coal. It is expected as a supplier of brown coal in the UBC process in this study. In terms of quantity, brown coal is widely spread in South Sumatra. The brown coal used as a raw material was mined brown coal from PT. Bukit Asam with a measured heating value of 4.000 to 4.200 kcal/kg. UBC pilot and demonstration plant

that has been running have the characteristics of raw materials in accordance with brown coal from PT Bukit Asam mentioned above [8].

Analysis Schematic diagram of the method in this research can be seen in Fig. 2. Then, to facilitate the calculations in this study due to the possibility of rapid changes in the data during the production process would require some assumptions. In this study, the calculation of the production costs was based on the following assumptions.

- The increase in the calorific value and the characteristics of the UBC product obtained from the production processes at the UBC Pilot Plant Palimanan, Cirebon.
- The location of the power plant used in order to reduce GHG emissions for domestic need is close to the UBC plant.

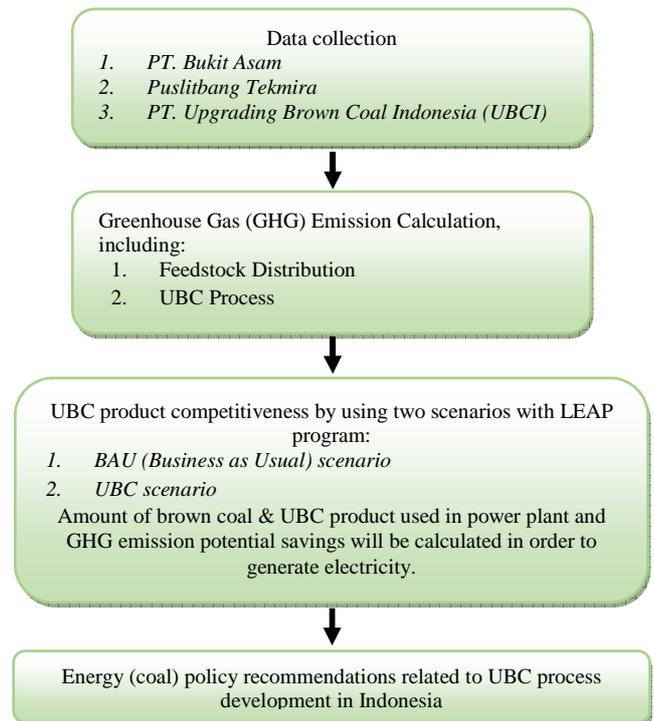


Fig. 2 Analysis Schematic Diagram

A. Greenhouse Gases Emissions Calculations

This calculation includes GHG emissions generated during the transportation phase and the UBC process itself as shown in Fig. 3. In the transportation phase, the calculation is divided into feedstock distribution from suppliers to UBC plant and UBC product distribution. UBC product distribution is separated into domestic and export purposes.

1) *Feedstock Distribution*: In this section of brown coal from PT. Bukit Asam as a feedstock was distributed to the UBC Plant. This distribution was carried out using a truck with the distance of 3.8 km

2) *UBC Process*: Potential GHG emissions were produced from electricity supply in order to run the process and the UBC process itself. The UBC process in this study is analyzed by the UBC demonstration plant in Satui, South Kalimantan. This UBC process was divided into 5 sections as listed in Fig. 4, namely [9]:

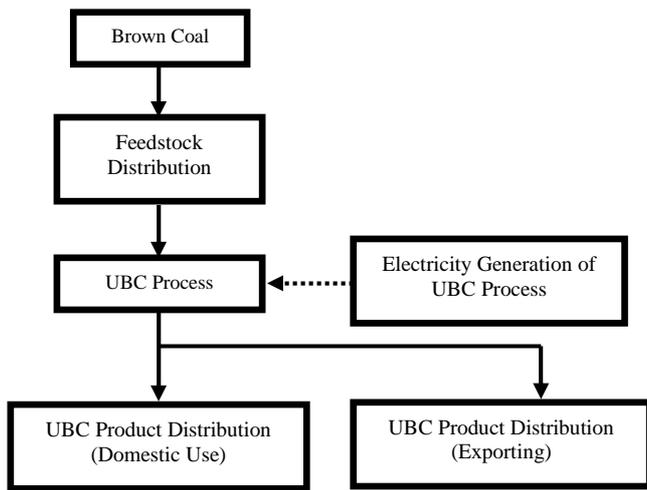


Fig. 3 Boundary system of greenhouse gas emission calculations

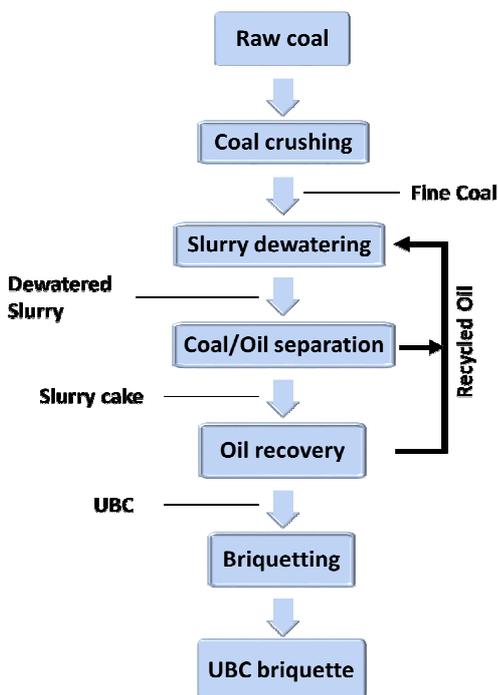


Fig. 4 Block diagram of Upgrading Brown Coal (UBC) process

- Coal preparation or coal crushing
- Slurry dewatering
- Coal-oil separation
- Oil recovery
- Coal briquetting

3) UBC Product Distribution

As mentioned earlier, the distribution of the product UBC adopted the system conducted by PT Bukit Asam. Here are the explanations of the UBC product distribution.

- Domestic
For domestic sales, the UBC product will be distributed using the train until the end of the pier located in Kertapati, Palembang. Therefore, the calculation of GHG emissions would include generated along the way from UBC plant towards to

the location (Kertapati) with a distance of ± 160.94 km.

- Export
The UBC product will be distributed to the Port which is located Tarahan, Lampung, for export purposes. This trip was conducted with the distance of ± 409.52 km by train.

GHG emissions are presented in carbon dioxide equivalent (CO₂ eq) units. It can be determined from the equation for the transportation sector

$$\text{Emissions} = \sum_{ij} (\text{Fuel}_{ij} \times \text{Ef}_{ij}) \quad (1)$$

B. UBC Product Competitiveness

The reason for UBC process application development in Indonesia is to increase the added value of brown coal. Therefore, UBC competitiveness product can be measured by comparing the UBC product with brown coal as usual. Brown coal and UBC product will be used as fuel to generate electricity at the power plant with the same condition.

There are two scenarios used in this calculation. Data for each scenario is taken by the combustion process of brown coal and the UBC product in the boiler. UBC product competitiveness was shown by the difference between the two scenarios. In this study, the technical data was taken from the 660 MW power plant. Furthermore, the calculation was performed using the LEAP program (Long-range Energy Alternative Planning system).

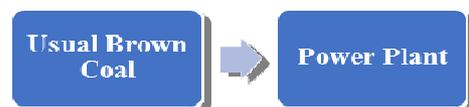
LEAP, is a widely-used software tool for energy policy analysis and climate change mitigation assessment. LEAP is an integrated, scenario-based that can be used to track energy consumption and others. It can be used to account for both energy sector and non-energy sector greenhouse gas (GHG) emission sources and sinks.

In this study, each scenario has the same scope of the problem, so that the brown coal competitiveness with indicators as follows will be calculated:

- Brown coal / UBC product consumption as feed in power generation.
- GHG emissions potential savings based on these two scenarios

The description of BAU and UBS Process scenarios used in this work can be explained as follow:

1) BAU (Business as Usual) Scenario



It is assumed that there is no upgrading process or brown coal as usual which has 36% moisture content. Then, it is used as a feed of combustion process in a boiler in order to generate electricity.

2) UBC Process Scenario



In this scenario, brown coal through the UBC process firstly and its product will be used to generate electricity. In this scenario, the characteristics of UBC product which have only 8% of moisture content was taken from the UBC pilot plant and the UBC plant. The total feedstock needed and heat losses during the combustion process in a boiler compared to the brown can be calculated.

C. Energy Policy Recommendations

This policy recommendation is expected to be a way to maximize the development of the UBC process which is being applied in Indonesia. Some problems in the development of this process will also be analyzed in order to get an appropriate way out. The policy recommendations are prepared by the field of techno-economic has been done on this study, so the results cannot be applied directly considering a policy was influenced by the political conditions of a country that is not being in the scope of this study. However, these policy recommendations could be advanced considerations in order to support the development UBC process as added value in low-rank coal and increase state revenues of Indonesia.

These results will be used to promote the development of the UBC process in Indonesia and to make policy recommendations in the field of coal as part of a way to increase the added value of brown coal. This is in accordance with the Energy Mix Target Indonesia, as stated in Indonesian Government Regulation No. 79 of 2014 on National Energy Policy that targets coal as a primary energy source in 2025 and 2050. However, if the UBC product is not competitive in the market, the result of the study will discuss the strategy to improve the competitiveness of UBC product.

III. RESULTS AND DISCUSSION

A. Greenhouse Gases Emissions (GEP) Calculations

1) Feedstock Distribution

Data obtained from PT. Bukit Asam stated that the required amount of fuel as much as 0.143 l/km in each carriage. Therefore, the data obtained are presented in Table 2.

TABLE II
GEP CALCULATIONS OF FEEDSTOCK DISTRIBUTION

Details	Data
Type of Transportation	Truck
Truck Capacity	30 tons brown coal/truck
Type of Fuel	Diesel
Total amount of fuel	0.54 l
Functional Unit	Per ton capacity
Total GEP	0.06 kg CO ₂ -eq

2) UBC Process

UBC process is free from chemical reactions which use simple an operation conditions, therefore it has a relatively low risk in the process [9]. UBC process is evident from the recycle system of heat generated in this process to be reused

in some processes. The UBC process takes place in close and recycles system so it can be assumed that is almost no emissions formed during the process. So that, the emissions during the UBC process only results from power generation. The UBC product used as energy source to run the process with data was shown in Table 3.

TABLE III
GEP CALCULATIONS OF UBC PROCESS

Details	Data
Capacity of Power Plant	48.67 MW
Type of Fuel	Brown coal
Operational Time	300 days/year
Functional Unit	Per ton capacity
Total GEP	74.45 kg CO ₂ -eq

3) UBC Product Distribution

- Domestic

The amount of Carriage in the train used to distribute UBC product in the domestic area is 35 carriage with capacity 30 tons UBC product/carriage. The total capacity and GEP potential formed can be seen in Table 4.

TABLE IV
GEP CALCULATIONS OF UBC PRODUCT DOMESTIC DISTRIBUTION

Details	Data
Type of Transportation	Train locomotive CC 201
Train Capacity	1,050 tons UBC product
Type of Fuel	Diesel
Total amount of fuel	827.23 l
Functional Unit	Per ton capacity
Total GEP	2.11 kg CO ₂ -eq

- Export

Slightly different from the trains used to distribute UBC product domestically, to meet the needs of the UBC product exports transported by train with 50 carriages per each train to port in Tarahan, Lampung. Table 5 is presented the GEP calculation of UBC product Export distribution.

TABLE V
GEP CALCULATIONS OF UBC PRODUCT EXPORT DISTRIBUTION

Details	Data
Type of Transportation	Train locomotive CC 205
Train Capacity	2,500 tons UBC product
Type of Fuel	Diesel
Total amount of fuel	1,578.70 l
Functional Unit	Per ton capacity
Total GEP	1.69 kg CO ₂ -eq

Coal contributed 42% of emissions in 2012 to become the world's largest source of energy-related CO₂ emissions, but by 2040 its share declines to 38% [10]. One kilowatt-hour produced from coal in developing countries emits 20%

more carbon dioxide than in industrialized countries [11]. UBC to reduce CO₂ emissions can increase the thermal efficiency of coal utilization by at least 2-3% on existing PC and possibly up to 5% [12]. The effects of an increase in efficiency from, for example, 28 % to 33 % could be a reduction in CO₂ emissions up to 15% [13]. If carried out at the mine, coal upgrading can also reduce the energy required for transportation of coal, and thus, the associated greenhouse emissions.

B. UBC Product Competitiveness

Brown coal and UBC product are fed to the boiler and burnt to generate steam. In this process, the moisture content of the coal contained within will determine the heat losses that occur. Its high content of moisture will cause a massive loss of heat that occurs so that the amount of coal used to generate electricity will increase. Two scenarios were applied to show the difference in the amount of coal needed to generate electricity with the same capacity, 660 MW of power plant in 365 days/year as operation time.

UBC product use can reduce feed consumption were used by 50% compared to the use of brown coal. Coal consumption difference between two scenarios is 1,885,266.56 Ton. This occurs because the process of UBC can lose almost 80% of PT. Bukit Asam in Tanjung Enim is one of the largest company which produce coal. It is expected as a supplier of brown coal in the UBC process in this study. the moisture contained in the brown coal so as to increase the efficiency of combustion.

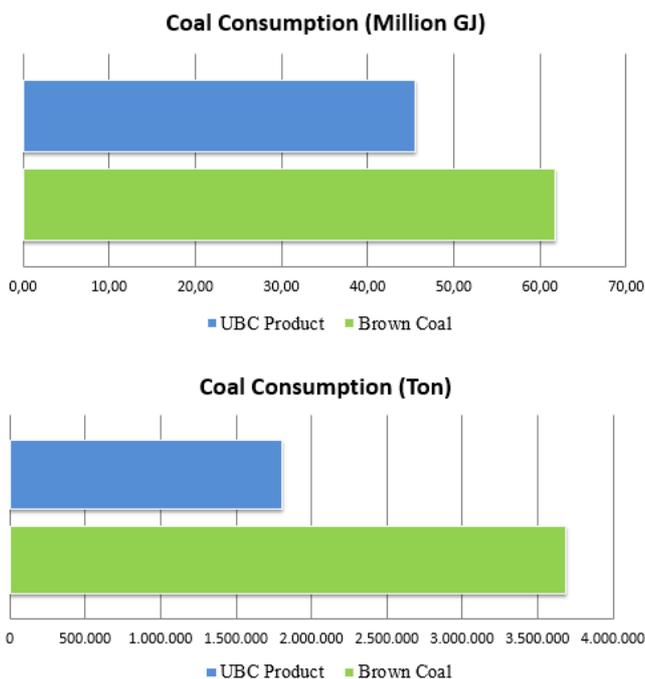


Fig. 5 Brown coal and UBC product consumption

Coal quality has a significant impact on many areas of power plant operation and performance, notably, capacity, heat rate, availability and maintenance [12]. Significant amounts of the energy in the coal are absorbed as heat to evaporate the water before any useful energy can be obtained and converted to electricity. The low quality of brown coal creates undesirable properties. Due to the high

moisture content and low fuel value, brown coal boilers need three to four times as much fuel to produce the same amount of electricity as black coal boilers. Therefore, boiler's fuel consumption will be reduced by 50 percent by using UBC product compared to brown coal as shown in Fig. 5.

The upgrading of thermal coal is intended not only to improve its combustion properties but to minimize the presence of abrasive and corrosive materials. These can affect pulverizers, classifiers, PC distribution pipes, heat exchanger tubes in the boiler and included draft fans. The presence of the mineral matter leads to fouling and slugging, cause reductions in the boiler thermal efficiency and the possible longer-term damage to the heat exchangers [9].

Furthermore, if you will in terms of greenhouse gas emissions occur potentially, it will be seen that the decrease of combustion of brown coal and UBC product. Greenhouse gas emission (GEP) saving potential as calculated is equal to 1,512,943,215.00 kg CO₂-eq/year (Fig. 6). Then, after calculating the GEP to run the UBC process it self, the net GEP saving potential obtained by 1,140,674,415.29 CO₂-eq kg/year. The decrease in greenhouse gas emission potential is often called global warming potential (GWP) does not occur with significant between combustion of brown coal or UBC product. This is consistent with the literature that has been mentioned previously that the UBC process will reduce greenhouse gas emission potential of ± 5% [12].

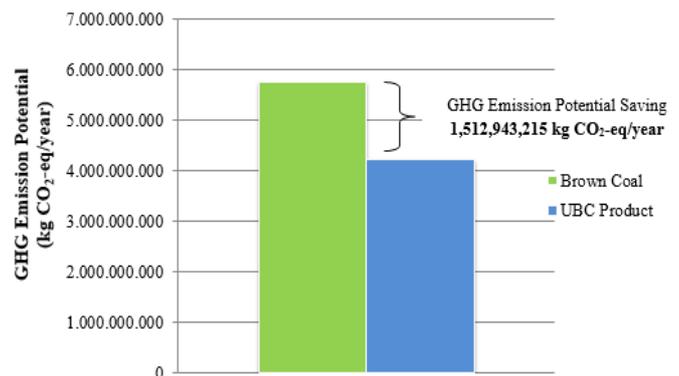


Fig. 6 GHG emission potential (kg CO₂-eq/year)

C. Suggested Strategies to Improve UBC Product Competitiveness

UBC product will compete to be developed in Indonesia in the future with a record needs to be some development in the long run. As mentioned previously, if the UBC process can be developed to improve the quality of brown coal with a calorific value lower than 3,500 kcal/kg, the UBC product will be much more competitive, because brown coal with a calorific value has not been widely used due to its low quality. This development will probably increase the costs of investment at the beginning but it can maintain the stability of the UBC process, in the long run, considering coal with a calorific value above 3,500 kcal/kg already has its own market today. In addition, the development of the technology used in power plants can also improve combustion efficiency and reduce levels emissions formed. Currently, Government of Indonesia (GoI) is being launched development of supercritical power plant in East Java that has not been commercially viable. As the government pushes

infrastructure and industrial development, the demand for electricity will increase and subsequently domestic coal consumption for electricity generation will increase [14]. Development and commercialization of some of the supercritical power plant can be a driving force for the increased use of UBC product in Indonesia to meet the electricity needs in Indonesia.

D. Energy Policy Improvements & Recommendations

The issues of energy supplies security will directly affect the national domestic and foreign of energy policies [15]. Immediate responsibilities for Indonesia's energy policy lie with the Ministry of Energy and Mineral Resources (MEMR). Policy for coal is the responsibility of the Directorate General of Minerals, Coal, and Geothermal (DGMC&G). Energy policies objectives in Indonesia are based on the Presidential Decree No.5 of 2006 on National Energy Policy and its Blueprint of National Energy Management 2006 – 2025.

Then, in order to manage the coal policy in Indonesia, there was the National Coal Policy (NCP) which was established by MEMR in 2004 [16]. NCP has the following principal objective which was suitable for the development of UBC Process in Indonesia, namely:

- Coal industry should be able to compete globally and offer an internationally competitive investment framework
- All quantities of coal reserves, including lower quality coals, are to be developed

In 2015, Indonesia relied on coal for 80.72% of the total domestic coal consumption (70 million ton of coal) for steam power generation [17]. Having population growth of 1.3% and annual economic of 6.1%, respectively, the need for electricity is estimated to grow around 9.2% per year [18]. Meanwhile, renewable energy share in the country's energy mix grows very slowly. Therefore, coal-fired power plant is seen as a viable option to meet Indonesia's energy need due to its abundant availability and stability of supply. It is projected that country's consumption of coal in 2020 will be two-point-five-fold of in 2005, reaching 75 million tons with CO₂ emissions increasing from 69.4 million tons in 2005 to 171 million tons in 2020 [19].

In the Law No. 4/2009 concerning mineral and coal mining, the added value of coal is one of the considerations in which UBC is an example of an implementation to add the value of coal itself [20]. Article 102 of that regulation outlines that the holders of Mining Business Licences (IUP) and special Mining Business Licences (IUPK), are required to increase the added value of mineral resources and / or coal in the implementation of mining, processing, and refining, as well as utilization of mineral and coal. Then, Article 103 paragraph (1) and (2) explains that holders of mining permit IUP and IUPK required to process and refine the results of its mine in the country, and can perform processing and refining of other IUP and IUPK. Then it also stated from Article 103 paragraph (3) that Further provisions on the need to increase the added value as referred to in Article 102 as well as on the processing and purification as referred to in paragraph (2) are to be provided for in a government regulation. From the regulation, it is clearly stressed on how

important the increasing of added value in the coal mining business under government regulation today and the future.

Several years ago, there was small share in energy market over the brown coal due to its high moisture content, low calorific value and tendency to generate greater total emissions. The high amount of coal utilizations as an energy source will cause a high demand for coal, including brown coal. Therefore, nowadays the coal with a calorific value below 5000 cal/g become having its own market.

The mining that frequently occurs nowadays is currently more focused on earning profits quickly even with small amounts so that the coal that is obtained is directly sold without going through the added value process. A number of mining processes that should be controlled and owned by Government of Indonesia (GoI) seem to grow poorly [21]. GoI has regulation for coal mining in accordance with this, namely the President Regulation No.1 in 2014. In accordance with the foundation of government in the Constitution of 1945 Article 33, paragraph 3, which reads " *Earth, water and natural resources contained therein is controlled by the GoI and used for the prosperity of the people in Indonesia*", if it can run properly then the mining process can be optimized and precisely target. Unfortunately, the implementation was not going well due to lack of supervision. Closer scrutiny of the mining that occurs is the key factor in increasing the possibility of direct sales of brown coal to the low price, then it can be enhanced its quality by the UBC process.

If the GoI could impose a more detailed policy, the mining companies would not export brown coal directly and increase the added value in accordance with the National Coal Policy (NCP). A large amount of coal exported to other countries indirectly was lead to decrease the selling price of coal and gave impact on the selling price of the UBC product. This could reduce the sustainability of the development of the UBC process in Indonesia. It is expected that the long-term brown coal can be enhanced and improved selling prices to then maintain the stability of coal prices in the world market.

Assertiveness from the Government of Indonesia (GoI) is necessary in order to implement a coal policy that prohibits the direct export of low-quality coal (brown coal) in order not to bring down the price of coal on the global market. Moreover, tighter supervision in sales of coal is also sorely needed.

In addition, cooperation with PT. Bukit Asam as brown coal supplier also becomes very important. Cooperation between UBC plants with brown coal suppliers so as to obtain brown coal (feedstock) with cheaper price compared to its market price. The government's role as a link both of the two companies could generate an agreement that can give benefits to both companies.

The sustainability of UBC process development in Indonesia is urgently needed. It can be done by improving the yield of the generated UBC product be above 82%. In the future, brown coal with a calorific value below 3,500 cal/g which is difficult to be marketed in the international market and still very rarely used for domestic purposes can be increased the quality through UBC Process.

UBC technology development can also reduce the production costs in the long-term. UBC technology can be

further developed to improve the quality of coal with a calorific value below 3,500 cal/g considering the price of brown coal with that quality that is much lower than the feedstock which is used in this study, 4,000 cal/g. Therefore, cooperation and commitment that has been constructed together by the Indonesian Ministry of Energy and Mineral Resources (MEMR) and Kobe Steel Ltd have to be developed better in the future.

IV. CONCLUSIONS

UBC product use can reduce feed consumption by 50% compared to the use of brown coal. Furthermore, when compared with the greenhouse gas emission potential (GEP) which occurs between the two scenarios is the importance of the number 1,512,943.215.00 kg CO₂-eq as saving and CO₂-eq kg 1,140,674,415.29 as net saving. The Government of Indonesia should pay attention to the mining sector and UBC process development sector to support the Energy Mix Target by 2025. Only by the reduction in feedstock price, improvement in the UBC product conversion and also the prevention direct sales of brown coal, then UBC process will be further developed. Indonesia may also get a bigger profit for a long time from that process.

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