

# The potential share of coal liquefaction in the Indonesian economy in 2025

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**Abstract:** One of the objectives of the National Energy Policy (KEN) of Indonesia which is listed in Perpres (Presidential Regulation) number 5/2006 is the realization of an optimal energy mix in 2025 by lowering oil consumption to 20% and increased utilization of coal to greater than 33%. KEN also mandates that more than 2% of national energy needs is derived from coal liquefaction process. This research aim is to analyze the economic impact and linkages among sectors using Indonesian 2005 Input-Output Table which will be projected to 2025 by entering low-rank coal synthetic oil (CSO) sector as a new classification. Econometric models (regression analysis) and linear programming are applied in this research. The result of economic calculation of investment in CSO plants indicates that on the coal price assumption of US\$60/ton, synthetic coal oil price of US\$111/bbl, and the interest rate (i) 5%, in general will give the Internal Rate of Return (IRR) is less than 10%. Analysis of backward linkages shows that the CSO sector will have a potential increasing a new output for the economy higher than the other energy sectors, but lower rate of forward linkage (downstream). Meanwhile, the multiplier effect indicates that the development of CSO plant is capable of moving national economy sectors equivalent to the petroleum refining sector and other energy provider sectors. The lower surplus multiplier shows that the investment in the CSO sector will be attractive if the government gives incentives on the enterprise, things such as regulation and investing financial support, tax incentives/tax holiday, price subsidies, and the coal prices scheme arrangements.

**Keywords:** Energy Policy, Coal Liquefaction, Linkages, Multiplier, Linear Programming

## 1. Introduction

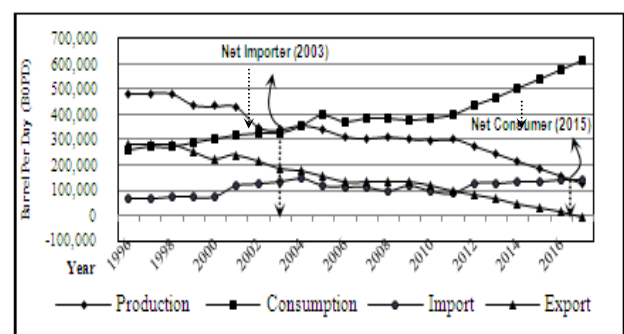
Oil plays an important role in the Indonesia's economy, either as fuel, raw materials of the production, or export commodity which until recently still is an important source of government revenue. Indonesia's dependence on oil in the long term threaten the sustainability of the national economic growth. In fact in recent years Indonesia has become net importer of petroleum.

Meanwhile, Indonesia has coal resources of 105.2 billion tons, of which about 21.1 billion tonnes are reserves. Some of these resources, approximately 20.2% (21.25 billion tons) is low rank coal (Badan Geologi, 2012).

If each ton of low rank coal can be converted into two barrels of synthetic oil, it can produce about 42.5 billion barrels of synthetic oil (Daulay, 2008). This amount is 10.5 times the proven oil reserves of Indonesia which is currently at 4.04 billion barrels (per-January 2011).

CSO as an alternative fuel would save foreign exchange by considering that since 2003 Indonesia has become a net

importer of petroleum and 2015 could be a net consumer if new reserves aren't found (Figure 1).



Source: DitjenMigas 2012 and reprocessed

**Figure 1.** Crude Oil Supply and Demand (Bbl Oil Per Day/BOPD)

Indonesia in cooperation with Japan (NEDO) has conducted several feasibility studies of development of liquefaction plant through technology of improved-Brown

Coal Liquefaction (I-BCL). The production of I-BCL is in the form of synthetic crude oil whose characteristics are similar to petroleum. Through the stages of fractionation and purification, the crude oil can be converted into premium (gasoline), kerosene, diesel oil/diesel, and other chemical products (Huda, 2008) (Table1).

The result of the feasibility study conducted in PT Arutmin, Mulia, South Kalimantan and PT Pendopo Energy Coal, South Sumatera shows that the economies level of

liquefaction plant is influenced by the quality parameters of coal as raw material (Tables 2 and 3).

Economic calculation results are showing that on the assumption of coal price of US\$60/ton, oil price of US\$111/bbl synthetic, and the interest rate (i) of 5%, CSO plant investment in larger capacity, generally will provide the Internal Rate of Return (IRR), Profitability Index (PI), and Payback Period are better when compared with smaller capacity plant (Table 3).

**Table1.** The product spesification of coal liquefaction (I-BCL)

Fuel Type	Unit	I-BCL Products	Industry Standard	
			Indonesia	Japan
<b>Gasoline:</b>				
-Octane Number		Min. 90	Min. 88	Min. 89
-Sulfur Content	Wt %	Max. 0.005	Max. 0.2	-
<b>Kerosene:</b>				
-Smoke point	Mm	Min. 16	Min. 16	Min. 23
-Sulfur Content	Wt %	Max. 0.005	Max. 0.2	Max.0.015
<b>Gas Oil:</b>				
-Cetane Number		Min. 45	Min. 45	Min. 45
-Sulfur Content	Wt %	Max. 0.005	Max. 0.5	Max. 0.2

Source: Direktorat Jenderal Minyak dan Gas, 2012; Direktorat Jenderal Mineral dan Batubara, 2012; Huda, 2008; Daulay, 2008.

**Table 2.** Feed coal characteristics of coal synthetic oil pilot plant

Quality Parameter	Mulia	Pendopo
* Total Moisture (ar)	35.00%	55.00%
* Proximate analysis (adb)		
- Inherent Moisture	23.00%	15.90%
- Ash	3.90%	7.80%
- Volatile matters	38.10%	44.80%
- Fixed carbon	35.10%	31.60%
- Total sulphur	0.15%	2.50%

Source: Huda, 2008

**Table 3.** Analysis result of financial aspect of coal synthetic oil plant

Plant Capacity	IRR (%)	NPV (US\$)	PI	Payback Period (Years)
Mulia Coal:				
* 3000 (t/d)	5.78	158,186,264.13	1.11	17.98
* 6000 (t/d)	7.06	876,090,838.51	1.37	13.02
* 12000 (t/d)	9.17	2,746,042,296.88	1.66	9.98
Pendopo Coal:				
* 3000 (t/d)	0.43	-769,597,990.71	0.49	56.71
* 6000 (t/d)	3.23	-567,477,287.41	0.77	29.29
* 12000 (t/d)	4.70	-176,190,295.91	0.96	21.95

Source: Huda, 2008 and re-calculated.

## 2. Theory and Methodology

### 2.1. Theory

In the long effort of the development of coal diversification in Indonesia that 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. Since there are available domestic large quantity of coal resources, then all efforts of coal diversification are carried out to overcome the energy problem, towards utilizing the new and renewable energy

sources in the future. Diversification of coal utilization may include several processes as the followings:

#### a. Direct utilization.

In the world wide coal has be used as direct fuel in industry for instance steam generating power plant, cement industry, steel plant, drying oven, small industry.

#### b. Indirect utilization.

Indirect coal utilization could be carried out in several processes:

#### i. Coking process.

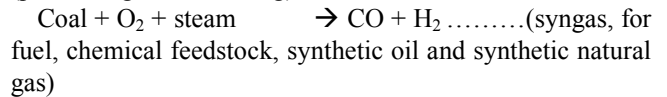
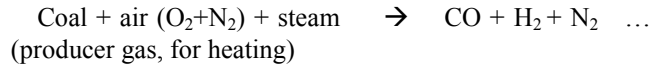
Coking process or carbonization is principally conducted by reducing the content of volatile content in coal, so that

its content of fixed carbon increases in lieu with the increasing its porosity. The product of coke has usually high compressive strength, content of fixed carbon and calorific value. The coking process could be carried out through either direct process or double process, depending on the purpose of coke making and the quality of coal. Domestic consumption of cokes which is mostly for iron casting, is around 140,000 tons per year but still be imported. It is expected that the domestic production of foundry cokes could be met soon (Anonymous (d), 1980; Soelistijo, 2011).

ii. Coal gasification. (Anonymous (b), 2008; Anonymous (a), 2007; Anonymous (c), 2000; Anonymous (d), 1980).

Principally, coal gasification process converts solid coal mass into synthetic gas that could 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. MCTRDC has developed direct coal gasification process resulting producer gas for tea leaf drying in the tea plantation and also for mixed oil-gas fuels in diesel generating power plant. In principle, the chemical reaction of resulting syngas and producer gas is as the followings:

*gasification*



iii. Coal liquefaction. (Anonymous (d), 1980; Anonymous (e), 2002; Anonymous (f), 2003; Wasaka, 2006).

Coal liquefaction process has four flows of processes (Figure 2) as follows:

- Pyrolysis or carbonization.
- The example processes: COED, TOSCOAL, GARRET and Clean-coke have been developed.
- Solvent extraction.
- The example processes: CSF (Consol Synthetic Fuel Process (CSF 2-3 : 1 solvent/coal ratio), SRC (Pittsburgh & Midway solvent refining process).
- Hydrogenation by using catalyst.
- The example processes: H-Coal process, Synthetic oil process, CCL (Catalytic Coal Liquefaction) process.
- Indirect liquefaction.
- The new direct liquefaction by using catalyst is being developed by JICA Japan.

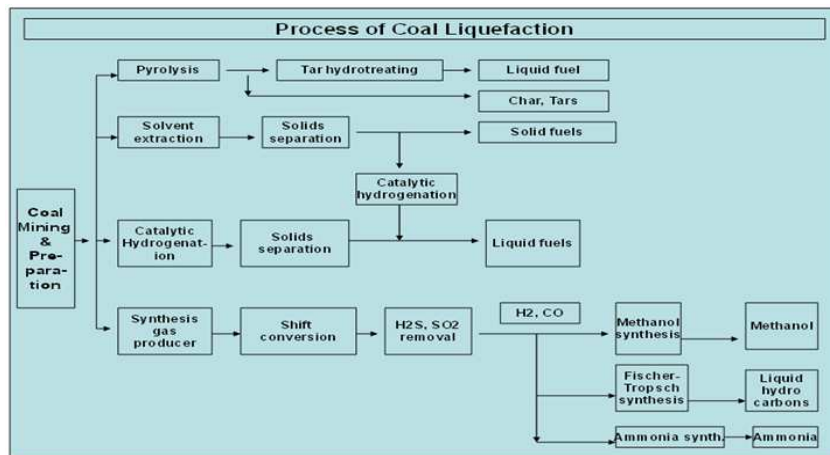


Figure 2. Several flows of coal liquefaction process

Besides coal could be utilized as fuels, it can also be used as non-fuel usage such as activated carbon, and other chemical substances.

**2.2. Methodology**

This study aimsto quantify the economic impact ofthe utilization of low quality coal through coal liquefaction process using an Input-Output model based on Indonesian 2005 Input-Output Table, 175x175sectors, domestic transactions on the basis of producer prices (Badan Pusat Statistik, 2005).

This table will be projected to year 2025 by entering alow-rank CSO sector asa new classification. The projection will be carried out in two assumptions that are the Scenario 1 (S<sub>1</sub>, low) with an economic growth of 6% and Scenario 2 (S<sub>2</sub>, high) with 7% in 2010-2015 and 8% in 2015-2025 (Menko Perekonomian, 2011). Final demand will be projected based on regression analysis, while optimization using linear programming.

The output valueof CSO sectors that is allocated to meet the demand for intermediate and final demand is 80.5 million barrels (BP-PEN, 2010).While the value of goods and services used as inputs in the production of CSO will be based on the results of a feasibility study of coal liquefaction plant (Huda, 2008; Anonymous (g), 2011; Anonymous (h), 2011; Soelistijo, 2003, 2013).

How high the linkage strength of the CSO sector with the the other sectors is measured by the backward (α<sub>j</sub>) and forward (β<sub>i</sub>) linkages. The backward linkage measures the yield of the CSO sector compared with input sectors, and forward linkage measures the strength of linkge of the CSO sector with the other sectors in creating higher added value. Multiplying analysis is used to clarify changes in the endogenous variables that are sectoral output as response to changes in exogenous variables in this case of final demand. The analysis results are used to set targets and allocation of development. Multiplying effects may include such as surplus-, investment-, added value-, and employment

multipliers. In particular, surplus multiplier indicates how far the development of CSO plant development in Indonesia provide enough surplus for the investors. Moreover, to evaluate the potential desired objective optimally in the scope of inputs and or outputs sectors, linear programming Input-Output model is applied subject to the available constraints due to the limited resources available. All in all, the entire study would like to see in depth how far the plan of CSO plant development in 2025 based on the certain scenarios is expected to contribute to the national economy output.

### 3. Analysis and Discussion

#### 3.1. Input-Output Model Definition

I-O Table is a comprehensive data set, consistent, and detailed statistical description of shape in the matrix.

That shows the structure of an economy's entire production system for a particular period of time, usually for a calendar or financial year. It shows goods and services produced by each industry, how such goods and services are used by different users; whether as intermediate inputs in production or final consumption.

##### 3.1.1. Relationship of the Entries in the I-O Table

The relationship between the entries in I-O Table and GDP are as follows:

$$\sum_j X_{ij} + Y_i - M_i = X_i \quad (i = 1, 2, \dots, n) \tag{1}$$

Where:

$X_{ij}$  = transactions from  $i$  sector to  $j$  sector,

$Y_i$  = final demand of  $i$  sector,

$M_i$  = imports of  $i$  sector,

$X_i$  = total output  $i$  sector.

$$\sum_i X_{ij} + V_j = X_j \quad (j = 1, 2, \dots, n) \tag{2}$$

In this case  $V_j$  is the primary inputs (value added) of  $j$  sector. Because  $X_i = X_j$ , the formula can be written as follows:

$$\sum_j X_{ij} + Y_i - M_i = \sum_i X_{ij} + V_j \text{ or } Y_i - M_i = V_j \tag{3}$$

From the I-O table, the technical coefficients ( $a_{ij}$ ) measure the input requirements per unit of product. These coefficients stated as the ratio between the outputs of  $i$  sector used in  $j$  sector ( $X_{ij}$ ) with total input  $j$  sector ( $X_j$ ) is determined as follows:

$$a_{ij} = \frac{X_{ij}}{X_j} \text{ or } X_{ij} = a_{ij} \cdot X_j \tag{4}$$

Furthermore, output in the I-O models calculated by the equation:

$$\begin{aligned} (I - A) X &= Y \\ X &= (I - A)^{-1} Y \end{aligned} \tag{5}$$

In the equation written above,  $(I - A)^{-1}$  is the inversed matrix from  $(I - A)$  or it can be called as Leontief inversed matrix (Bulmer, 1982; Nazara, 2005; Soelistijo, 2013).

##### 3.1.2. National Output Projections

Output in the economy of a country in the I-O model developed by Bulmer can be calculated as follows:

$$X = (I - A)^{-1} Y \tag{6}$$

where:

$Y$  = final demand,

$I$  = identity matrix,

$A$  = technical coefficient.

Leontief inversed matrix  $(I - A)^{-1}$  is very important to analyze the economy because of inter-related with the level of final demand to the estimation of production rate. Changes in industry output can be predicted using the Leontief inversed matrix.

##### 3.1.3. Intersectoral Linkages Analysis

This analysis is used to look at their impact happened on output of a sector as a result of changes in final demand in each sector of the economy. Impact of industrial linkages between sectors can be observed through backward linkages and forward. Backward linkages of a sector with other economic sectors in a region/country (Bulmer, 1982, Miernyk, 1965, 1982) are calculated with the formula:

$$\alpha_j = \frac{(1/n) \sum_i b_{ij}}{(1/n^2) \sum_i \sum_j b_{ij}} \tag{7}$$

While a sector forward linkage with other sectors is used an equation:

$$\beta_i = \frac{(1/n) \sum_j b_{ij}}{(1/n^2) \sum_i \sum_j b_{ij}} \tag{8}$$

##### 3.1.4. Multiplier Analysis

Multiplier analysis is used to see changes in the endogenous variables that are sectoral output as response to changes in exogenous variables such as final demand (Nazara, 2005). The results of the analysis are used to set targets and allocation of development.

#### 3.2. Linear Programming Approaches

Linear programming I-O models is a mathematical model for utilizing the limited resources in meeting the desired objectives optimally in the scope of input and output sectors.

Value projection in the I-O table is not necessarily the optimal value, because it will be optimized using linear optimization program with the objective function to maximize the final demand ( $Y_i$ ) and total output ( $X_i = X_j$ ) in I-O Table 2025 (coefficient of objective can be seen in Tables 4 and 5).

Table 4. Objective function coefficient of I-O Table in Scenario 1

No.	Sector/Industry	Final Demand (Y)	Total Output (X)
1	Coal mining	0.815679	1.282149
2	Coal synthetic oil	0.644245	1.520398
3	Natural gas and geothermal mining	0.861802	1.221582
4	Petroleum refineries products	0.923090	1.128445
5	Other sectors	0.588596	1.671504

Source: 2025 IO Table in Scenario 1

**Table 5.** Objective function coefficient of I-O Table in Scenario 2

No.	Sector	Final Demand (Y)	Total Output (X)
1	Coal mining	0.815679	1.282249
2	Coal synthetic oil	0.631941	1.556405
3	Natural gas and geothermal mining	0.861802	1.221644
4	Petroleum refineries product	0.923116	1.128440
5	Other sectors	0.588471	1.672003

Source: 2025 I-O Table in Scenario 2

In this linear program will be used five decision variables, that is coal mining sector, CSO, natural gas and geothermal mining, petroleum refineries product, and other sectors which is a combination of 21 other economic sectors.

While limit function for each economic sector are import and primary inputs (added value) that indicating the amount of the remuneration of the factors of production, which consists of wage and salary, operating surplus, depreciation, indirect tax, and subsidy (See Tables 6 and 7).

**Table 6.** Minimum limit coefficient of primary input (Scenario 1)

No.	Sector (Constraint)	Coal mining	Coal Synthetic Oil	Natural Gas and Geothermal Mining	Petroleum refineries product	Others
1	Capital	0.04763	0.12057	0.02302	0.08838	0.04989
2	Labor	0.16092	0.00664	0.05645	0.22337	0.15545
3	Operating Surplus	0.54171	0.29297	0.73684	0.64457	0.27001
4	Indirect Tax	0.03359	0.17407	0.04176	0.00641	0.01948
5	Subsidy	0.00000	0.00000	0.00000	-0.36055	-0.00223
6	Imports	0.03184	0.05000	0.00373	0.32091	0.09601

Source: direct coefficient of 2025 I-O table in Scenario 1

**Table 7.** Minimum limit coefficient of primary input (Scenario 2)

No.	Sector (Constraint)	Coal mining	Coal Synthetic Oil	Natural Gas and Geothermal Mining	Petroleum refineries product	Others
1	Capital	0.04763	0.09536	0.02302	0.08838	0.04989
2	Labor	0.16092	0.00525	0.05645	0.22338	0.15556
3	Operating surplus	0.54171	0.23171	0.73684	0.64459	0.26972
4	Indirect tax	0.03359	0.24962	0.04176	0.00641	0.01944
5	Subsidy	0.00000	0.00000	0.00000	-0.36056	-0.00223
6	Imports	0.03184	0.05000	0.00373	0.32091	0.09609

Source: direct coefficient of 2025 I-O table in Scenario 2

**Table 8.** The projection result of final demand (Y) and total output (X) (IDR Trillion)

No.	Sector	2005	I-O Table in 2025 (Scenario 1)		I-O Table in 2025 (Scenario 2)	
			Actual	Optimal	Actual	Optimal
1	Final Demand	3,443.895	11,896.839	11,167.340	15,019.635	15,019.570
2	Total Output	5,688.274	19,813.284	32,727.790	25,022.737	41,350.150

Source: optimization result of I-O table using linear programming

The linear programming model is formulated as follows:  
Maximize:

$$Z = \sum_i \Delta Y_i = \sum_j (I - A) \Delta X_j; \text{ and } Z = \sum \Delta X_i = \sum_i (I - A)^{-1} \Delta Y_i$$

Subject to constraints:

Capital:  $\sum k_j X_j - D_h \leq K_h;$

Labor:  $\sum l_j X_j - E_h \leq L_h;$

Operating surplus:  $\sum s_j X_j - R_h \leq S_h;$

Indirect tax:  $\sum t_j X_j - P_h \leq T_h;$

Subsidy:  $\sum b_j X_j - F_h \leq B_h;$

Imports:  $\sum m_j X_j - I_h \leq M_h;$

Non-negativity:  $X_1 \geq 0, X_2 \geq 0, \dots, X_n \geq 0;$

where:

Z = objective function;

X = total gross output;

Y = final demand;

A = technical coefficient;

$k_j$  = capital coefficients;

$b_j$  = subsidy coefficients;

$K_h$  = available capital;

$B_h$  = available subsidy;

$l_j$  = labor coefficients;

$t_j$  = indirect tax coefficients;

$L_h$  = available labor;

$T_h$  = available indirect tax;

$s_j$  = operating surplus coef.;

$m_h$  = import coefficients;

$S_h$  = available surplus;

$M_h$  = available imports;

$D_h, E_h, R_h, F_h, P_h, I_h$  = disposal activities.

### 3.3. Coal Synthetic Oil Sector Impact on the Economy

#### 3.3.1. The Economies of Coal liquefaction Plant

Coal of Pendopo that has a higher moisture if compared with Mulia will cause a greater feed that will followed by the increase in the volume of equipment on the upstream plant, such as coal handling, water removal, and boiler design. Location of coal liquefaction plant on Pendopo also requires the availability of pipelines along the 200 km to the port in order to transmit CSO products.

Thus the cost of procurement and construction of Pendopo plant which is calculated based on the results of a feasibility study in 2002 if assuming the price increase around 3.5%/year will be US\$98 million higher compared with the Mulia plant. The operational cost of Pendopo coal liquefaction plant on the same coal price assumptions (US\$60/ton) will be higher (US\$88.65/bbl) than Mulia plants (US\$ 67.62/bbl).

The economic calculation result of CSO plant shows that the value of IRR is less than 10% making it less attractive to investors. The value of IRR will be influenced by the price of coal, product selling prices, interest rates, and the amount of tax imposed on the company.

CSO plants would be built as an integrated industry between mining and coal liquefaction thus more productive and efficient. The regulation of low rank coal prices could be made by government to ensure stability of supply and price. The investment of CSO plant would be more attractive to investors if the government can provide incentives, things such as:

- Reduction of coal production sharing (DHPB) and royalties;
- Reduction in corporate tax rate (PPh);
- Exemption of import duty for imported capital goods;
- Elimination of value added tax (PPN);
- Price subsidies.

#### 3.3.2. Linkages Analysis

The impact of linkage is an important analytical tool in order to describe the role of the production sector in the structure of the economy and set the key sectors in the development planning.

The result analysis of backward linkages ( $\alpha_j$ ) is known that in general, energy providers sectors give lower yields than average of economic sectors. However, the CSO sector is known to have backward linkages value higher ( $S_1: \alpha_3=0.942$  and  $S_2: \alpha_3=0.958$ ) when compared with petroleum refineries product sector ( $S_1: \alpha_{12}=0.679$  and  $S_2: \alpha_{12}=0.674$ ) and other energy provider sectors. Meanwhile, forward linkages ( $\beta_i$ ) indicate that CSO sector has lower value ( $S_1: \beta_3=0.731$  and  $S_2: \beta_3=0.734$ ) compared to the petroleum refineries product sector ( $S_1: \beta_{12}=1.333$  and  $S_2: \beta_{12}=1.336$ ) and other energy providers.

#### 3.3.3. Multiplier Analysis

The analysis of multiplier is carried out in an open method (Type I), which does not include household consumption as one of the sectors of production that is

considered as an exogenous factor that does not determine the economy's output.

#### 3.3.4. Output Multiplier

Output multiplier of CSO sector based on I-O table in 2025 on scenario 1 and 2 are 1.505 and 1.528. This means that any increase in final demand ( $\Delta Y$ ) in this sector amounted to IDR1 billion, it will create the output ( $\Delta X$ ) amounting to IDR1.505 billion and IDR1.528 billion.

Output multiplier of CSO is higher when compared to coal mining sector ( $S_1: OM=1.279$  and  $S_2: OM=1.275$ ), natural gas and geothermal mining ( $S_1: OM=1.159$  and  $S_2: OM=1.157$ ), and petroleum refineries product ( $S_1: OM=1.085$  and  $S_2: OM=1.075$ ).

This indicates the ability of this new sector in creating a new output for the economy higher than the other energy provider sectors.

#### 3.3.5. Income Multiplier

Income multiplier of CSO sector in scenario 1 and 2 are 3.85 and 4.60, which means that any increase in final demand ( $\Delta Y$ ) of IDR1 billion will increase the total revenue ( $\Delta N$ ) of the entire economy of 3.85 and 4.60 times than before.

The income multiplier of this sector is higher than the natural gas and geothermal mining sector ( $S_1: NM=1.94$  and  $S_2: NM=1.94$ ), petroleum refineries products ( $S_1: NM=1.58$  and  $S_2: NM=1.66$ ), and coal mining ( $S_1: NM=1.37$  and  $S_2: NM=1.36$ ).

This shows the potential of this sector in creating household income due to the absorption of labor in meeting its production.

#### 3.3.6. Surplus Multiplier

Surplus multiplier of CSO sector based on I-O table in 2025 on scenario 1 and 2 are 1.019 and 1.216. This means that any investment in this sector amounted to IDR1 billion would generate a surplus from operations of IDR1.019 billion and IDR1.216 billion.

The value of surplus multiplier is lower when compared to the natural gas and geothermal mining ( $S_1: SM=3.953$  and  $S_2: SM=3.961$ ), coal mining ( $S_1: SM=1.803$  and  $S_2: SM=1.807$ ), and petroleum refineries products ( $S_1: SM=1.222$  and  $S_2: SM=1.376$ ).

This indicates that the development of CSO plant in Indonesia provides enough surplus value for its investors.

#### 3.3.7. Investment Multiplier

Investment multiplier of CSO sector in scenario 1 and 2 of 1.242 and 1.333, which means that any increase in investment ( $\Delta I$ ) IDR1 billion, causing an increase in national income ( $\Delta Y$ ) amounting to IDR1.242 billion and IDR1.333 billion.

This investment multiplier is higher than coal mining sector ( $S_1: IM=1.392$  and  $S_2: IM=1.385$ ), natural gas and geothermal mining sector ( $S_1: IM=1.263$  and  $S_2: IM=1.260$ ), and petroleum refineries product sector ( $S_1: IM=1.036$  and  $S_2: IM=1.036$ ).

It means that investment in the CSO sector will have a direct impact on national income equivalent to the others

energy provider sector.

**3.3.8. Value Added Multiplier**

Value added multiplier of CSO on scenario 1 and 2 are 1.527 and 1.545, which means that any increase in final demand ( $\Delta Y$ ) of a sector IDR1 billion will be able to move the economy and generate added value in other economic sectors amounted to IDR1.527 billion and IDR1.545 billion.

The value added multiplier of CSO sector is higher than the petroleum refineries product ( $S_1:VM=1.119$  and  $S_2:VM=1.118$ ), natural gas and geothermal mining ( $S_1:VM=1.149$  and  $S_2:VM=1.149$ ), and coal mining ( $S_1:VM=1.195$  and  $S_2:VM=1.192$ ).

**3.3.9. Employment Multiplier**

Employment multiplier of synthetic coal oil sector in scenario 1 and 2 are 1.424 and 1.925, which means that any increase in final demand ( $\Delta Y$ ) in this sector of a unit of money, would drive the economy and absorb labor in other sectors amounted to 1.424 and 1.925 units.

The employment multiplier shows a higher value than coal mining sector ( $S_1:LM=1.294$  and  $S_2:LM=1.290$ ), natural gas and geothermal mining sector ( $S_1:LM=1.279$  and  $S_2:LM=1.275$ ) and petroleum refineries products ( $S_1:LM=1.036$  and  $S_2:LM=1.036$ ).

**3.3.10. The Role of Coal Synthetic Oil in the Economy**

The plan for CSO plant development in 2025 on the scenario is expected to contribute to national economic output of IDR65.033 trillion and in scenario 2 of IDR82.226 trillion, or 0.33% of the total output ( $X$ ).

Objective Function:

$$Y = 0.816X_1 + 0.644X_2 + 0.862X_3 + 0.923X_4 + 0.589X_5$$

Subject to the constraints:

- Capital:

$$0.05X_1 + 0.12X_2 + 0.02X_3 + 0.09X_4 + 0.05X_5 \leq 1,005,800,909.34$$

- Labor:

$$0.16X_1 + 0.01X_2 + 0.06X_3 + 0.22X_4 + 0.15X_5 \leq 3,086,439,072.51$$

- Operating surplus:

$$0.54X_1 + 0.29X_2 + 0.74X_3 + 0.64X_4 + 0.27X_5 \leq 5,637,843,521.49$$

- Indirect tax:

$$0.03X_1 + 0.17X_2 + 0.04X_3 + 0.01X_4 + 0.02X_5 \leq 395,956,904.61$$

- Subsidy:

$$0.00X_1 + 0.00X_2 + 0.00X_3 - 0.36X_4 - 0.00X_5 \leq -204,058,195.92$$

- Imports:

$$0.03X_1 + 0.05X_2 + 0.00X_3 + 0.32X_4 + 0.10X_5 \leq 1,974,857,337.18$$

The optimization results in Table 8 shows that the impact of CSO sector to the national economy in final demand ( $Y$ ) has smaller value than the actual value. While the total output ( $X$ ) optimization results indicate that the optimal output has a greater value than the actual value.

Output of petroleum refineries products sector ( $X_{12}$ ) in 2005 amounted to IDR148.086 trillion, while in 2025 under scenario 1 of IDR448.409 trillion and scenario 2 of IDR566.686 trillion. In percentages, the contribution of  $X_{12}$  to  $X$  declined, from 2.6% in 2005 to 2.26% in 2025 for scenario 1 and 2.265% for scenario 2.

Contribution of CSO sector to final demand ( $Y$ ) in 2025 under scenario 1 is estimated at IDR7.537 trillion and in scenario 2 IDR9.419 trillion. The contribution of CSO sector ( $Y_3$ ) to  $Y$  is 0.063%.

While the contribution of the petroleum refineries products to the final demand ( $Y$ ) in 2005 amounted to 0.61% or IDR21.027 trillion.

In 2025 under scenario 1, the contribution of this sector to final demand is estimated at IDR52.278 trillion and in scenario 2 of IDR65.338 trillion. The average percentage of this sector to the final demand is about 0.44%.

**3.4. Input-Output Optimization**

Synthetic coal oil sector is expected to play an important role in the national economy in 2025. The impact of the utilization of low-quality coal can be done by looking at the value of output and final demand in I-O Table.

Optimization performed on total output and final demand from I-O Table 2025 in scenarios 1 and 2 on the five decision variables which are the sectors of energy providers.

Examples of maximization formulation of final demand ( $Y_i$ ) as follows:

**4. Conclusions**

The conclusions that can be drawn from the above analysis are as follows:

- 1) The economic calculations of CSO plant

development indicate a profitable investment prospects. The analysis result showed that in the coal price assumption of US\$60/ton, synthetic coal oil price at US\$111/bbl, and the interest rates ( $i$ ) 5%, the investment in CSO plant in greater capacity, for example, 12,000 tons of coal/day will give a better Internal Rate of Return (IRR) and Profitability Index (PI).

- 2) The result of backward linkage ( $\alpha_j$ ) analysis of CSO sector is known can only give a lower yield ( $S_1: \alpha_3=0.942$  and  $S_2: \alpha_3=0.958$ ) than the average of backward linkages sectors of economy, but higher than the petroleum refineries products ( $S_1: \alpha_{12}=0.679$  and  $S_2: \alpha_{12}=0.674$ ) and others providers energy sectors. One reason is the authorization of the national coal resources that is a source of raw materials for CSO industry by large mining companies. While the forward linkages ( $\beta_i$ ) of CSO sector is lower ( $S_1: \beta_3 = 0.731$  and  $S_2: \beta_3=0.734$ ) than others energy provider sectors that indicate the lack ability to encourage the growth of downstream sectors.
- 3) The multiplier of CSO sector in general shows the average values higher than the petroleum refineries products sector. These values indicate that the synthetic coal oil sector has the potential to create a new output that capable to drive the national economic sectors equivalent to the petroleum refining sector and other energy providers. However, this sector has a surplus multiplier value is lower than other energy providers sector who indicates that CSO plant investment is less able to provide operating surplus that attractive to investors.
- 4) Government can provide incentives for investment of low rank CSO plant to make it more attractive to investors. The forms of incentives can be given such as regulation support, investing financial support tax incentives/tax holiday, price subsidies, etc.
- 5) The low value of final demand optimization results in 2025 I-O Table when compared to the actual value due to such:
  - a The value of final demand ( $Y=GDP$ ) in 2025 is estimated has reached the optimal value;
  - b CSO industry more efficiently when compared to petroleum refinery as it uses domestic low rank coal and is located close to the mine site;
  - c CSO has an ability to attract economic growth in the upstream than downstream sectors.

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