The Optimization of Coal Supply for Planned PLTU in West Kalimantan Province

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Abstract: Based on PLN's RUPTL, to improve the reliability of the electricity system in West Kalimantan, the construction of non-fuel power plants such as the Parit Baru PLTU (FTP1 and FTP2) and the Pantai Kura-Kura PLTU (FTP1). In West Kalimantan, coal has not been exploited and coal reserves have also not been identified, so coal for PLTU must be supplied from other provinces. The effort to get the lowest overall coal procurement costs for PLTU demands, a study on optimization of coal supply for PLTU plans in West Kalimantan Province using the Linear Programming method. Linear Programming consists of objective functions and constraint functions. The objective function informing the model is used to minimize the total cost of procuring coal for power generation. While the constraint function is a linear relationship of the decision variable that reflects the limited supply of coal. The constraint function is divided into two types namely the constraint function from the supply and demand sides. The output is the distribution of coal from the Coal Company to the planned PLTU with the lowest total procurement costs. The minimum cost of procuring coal for PLTU demands is USD 2,565,963,000 in a year.

1 INTRODUCTION

Coal is an accumulation result of organic material derived from plant residues that have through a lithification process and become coal seams (Yonas, 2016). Based on the Handbook of Energy and Economic Statistics of Indonesia, the amount of Indonesia's coal reserves is 32 billion tons which are spread on the Sumatra and Kalimantan islands. Coal can be used in human life, such as power plant, iron and steel industry, space heating, fuel for cement production, fertilizer, paper mills, chemical, and pharmaceutical industries. Most of the domestic coal demand is currently used as a PLTU (Electric Steam Power Plant) fuel to produce electricity. Coal PLTU is the main source of electrical energy in Indonesia because of a large number of coal resources and the price is relatively cheaper than fuel oil.

Based on Government Regulation Number "PP 79 Tahun 2014" concerning the National Energy Policy, the optimal primary energy mix target by using primary energy sources for coal at least 30%, natural gas at least 22%, petroleum less than 25%, and EBT at least 23%. To support this achievement, RUPTL stated the electricity development plan for 2015 until 2019 includes the development of power plants, transmission networks, substations, and distribution networks. The addition of new power plants require for 5 years is 35 GW which is the PLTU provides the largest contribution.

Based on the MP3EI document (Master Plan for the Acceleration and Expansion of Indonesia's Economic Development) the theme of the development in Kalimantan Economic Corridor is as a Center for Production and Processing of National Energy and Mining Products. These economic activities can be developed and become engines of economic growth. West Kalimantan is one of the provinces which is the center of development in the corridor, so far most of the electricity supply in West Kalimantan is sourced from oil fuel power plants.

Based on the RUPTL (Electricity Supply Business Plan), at the end of 2015, the interconnection between West Kalimantan and Sarawak (Malaysia) began operations to reduce the cost of production by replacing oil fuel power plants, increasing the reliability of the West Kalimantan system, and anticipating delays in the construction of the PLTU project. Anticipate short-term power shortages, the Pontianak 100 MW Mobile Power Plant (MPP) was built. MPP can be mobilized if the power from the PLTU is sufficient.

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The reliability of the electricity system in West Kalimantan is enhanced through the construction of non-oil fuel plants such as the Parit Baru PLTU (FTP1 and FTP2) and the Kura-Kura Beach PLTU (FTP1). It's interconnected to the Equator system. Meanwhile, to reduce the cost of production in other subsystems, by build small-scale PLTUs such as Sintang PLTU and Ketapang PLTU. But West Kalimantan has not exploited coal and coal reserves have also not been identified, so coal for PLTU must be supplied from other provinces. To obtain the lowest overall coal procurement costs for the demand of PLTU while ensuring the continuity of electricity supply, it is necessary to study the optimization of coal supply for PLTU using the Linear Programming method (Mitra & Avittathur).

2 METHOD

Solving problems using Linear Programming required a model consisting of objective functions and constraint functions. The objective function is to minimize coal procurement costs with supporting variables including unit costs of coal production and transportation. While the constraint function consists of the demand function obtained from the calculation of coal demand from each PLTU and the supply function obtained from coal production for each type.

These are steps to obtain coal distribution for PLTU with the optimum cost.

1. Calculate the coal demand of PLTU.
2. Find the calorie value and coal reserves of each company that is obtained from the Ministry of Energy and Mineral Resources and the Indonesian Coal Book.
3. Find the quality of coal that will be used in each PLTU.
4. Design the objective function as well as the constraint function.
5. Solve optimization problems using WinQ SB software.

3 LINEAR PROGRAMMING

Linear programming is a mathematical application technique in determining problem-solving to maximize or minimize something that is limited by certain constraints, it also known as optimization techniques (Indah & Sari, 2019). Linear programming can be used as a deterministic tool, which means that a parameter model is assumed with certainty. Generally, the characteristics of Linear programming problems are the objective function in the form of minimization or maximization, and all constraints are in the form of equations or inequalities and the decision variable is not negative.

The following are the steps in Linear Programming modeling:

1. Determine unknown variables (decision variables) and express them in mathematical symbols.
2. Determine all the constraints of the problem and express in the equation or inequality which is also a linear relationship of the decision variable that reflects the limited resources or system boundaries that are modeled from the problem.

$$\sum A_{ij} X_{ij} \{\leq or = or \geq\} B_i, X_j \geq 0, \quad (1)$$

Index:
n = *Types of activities that use the source or facility*
i = Number of each type of source or available facility
j = Number of each type of activity that uses resources or facilities
X_j = j^{th} activity (decision variable)
A_{ij} = Number of sources i^{th} needed to produce each activity output unit j^{th}
B_j = The number of available sources i^{th}

3. Determine the goal (maximum or minimum) that must be achieved to determine the optimum solution of all feasible values of the variable (Putri, 2015).

$$Z = C_1 X_1 + C_2 X_2 + ... + C_n X_n \quad (2)$$

Index:
Z = Optimized value
Cn = Contribution of each unit of activity output n to the value of Z
Xn = n^{th} activity (decision variable)

4 PARAMETERS

4.1 Coal Demands

Based on the RUPTL, there are 5 PLTU in West Kalimantan Province that are under construction, including the Sintang PLTU, Ketapang PLTU, Baru Parit PLTU (FTP1 and FTP2), and Pantai Kura-Kura PLTU. Each PLTU has different generating power so that the coal demand for each PLTU is different. The

Table 1: Coal Demand of PLTU.

PLTU	Power (MW)	Calory (kkal/kg)	Coal Demand (kg)
Sintang	3 x 7	4,000	76,414,154
Ketapang	10	4,200	34,654,945
Parit Baru FTP 1	2 x 50	4,200	346,549,451
Parit Baru FTP 2	2 x 50	4,200	346,549,451
Pantai Kura-Kura FTP 1	2 x 27.5	4,000	200,132,308

Table 2: Coal Production in Mining Company.

Mining Company	Calory (kcal/kg)	TM (%)	TS (%)	Ash (%)	Production (ton)
PT Adaro Indonesia	4,000	40.00	0.20	3.00	50,601,101.00
PT Bara Multi Suksessarana	4,065	35.40	0.34	3.70	1,500,000.00
PT Borneo Indobara	4,000	38.00	0.50	6.00	4,003,273.74
PT Jorong Barutama Greston	4,400	32.00	0.25	4.15	203,887.00

following approach is used in calculating coal demand for each PLTU (Naiborhu, 2015).

$$V = \frac{P \times F \times cf \times t}{eff \times E} \quad (3)$$

Index:
V = Total Coal Demands (kg)
P = Generating Power (MW)
F = Conversion Factor
cf = Factor Capacity
t = Time in 1 year (hour)
eff = Combustion Efficiency
E = Coal Calorie (kcal/kg)

Energy unit conversions According to James Prescott Joule, a conversion factor value of 1 MWh = 8.64 × 105 kcal. In this study using a factor capacity value of 75%, generating efficiency of 39%, and the amount of time in a year is 8,760 hours (Sartika & Septiansyah, 2018). The calculation of coal demands in each PLTU are shown in Table 1.

Based on Table 1, it is known that the Sintang and Ketapang PLTUs are small-scale PLTUs with a capacity of 7 MW and 10 MW. Meanwhile, the PLTU Parit Baru and Pantai Kura-Kura are medium-scale power plants with a capacity of 50 MW and 27.5 MW. This affects the amount of coal demand needed to generate electricity. The demand for coal shows a large value with a large power generation capacity.

4.2 Coal Production

The coal used for a power plant is generally low-calorie coal (less than 4,200 kcal/kg). Each coal mining company produces coal with different specifications, from calories, total moisture, total sulfur, and total ash. In this case mining companies that will supply coal for PLTU from the island of Kalimantan. These following are the company that will supply coal to the planned PLTU in West Kalimantan.

Based on Table 2, it is known that PT Adaro Indonesia produces the most low-calorie coal which is 50 million tonnes with 4,000 kcal/kg calories. Meanwhile, PT Jorong Barutama Greston Indonesia produces the most low-calorie coal, which is 0.2 million tons with 4,400 kcal/kg calories.

4.3 The Selling Price of Coal

Coal has different selling prices, depending on the specifications of calories, moisture, total sulfur, and ash. The selling price of coal for PLTU has been regulated in Ministerial Decree of ESDM (Energy and Mineral Resources) Number: 1395K/30/MEM/2018 concerning the Selling Price of Coal to the Provision of Electric Power for Public Interest. The selling price of coal to the electricity supply for public use is USD 70 per metric ton of Free on Board (FOB) vessels, based on reference specifications on calories 6,322 kcal/kg GAR, total moisture 8%, total sulfur 0.8%, and ash 15%. Based on the selling price of coal aquation contained in the Minister of Energy and Mineral Resources Number 1395K/30/MEM/2018, the selling price of coal for each company is shown in Table 3.

Based on Table 3, it is known that the higher the coal calories, the higher the coal selling price. It will affect the cost of procuring coal. the cost of procuring coal will also increase with the use of coal for higher calories.

Table 3: The Selling Price of Coal.

Mining Company	Calory (kcal/kg)	TM (%)	TS (%)	Ash (%)	Selling Price (USD/ton)
PT Adaro Indonesia	4,000	40.00	0.20	3.00	28.87
PT Bara Multi Susksessarana	4,065	35.40	0.34	3.70	28.69
PT Borneo Indobara	4,000	38.00	0.50	6.00	34.53
PT Jorong Barutama Greston	4,400	32.00	0.25	4.15	42.55

Table 4: The Distance between the Seaports of Mining Company.

Mining Company	Distance from Mining Company to the PLTU (NM)				
	Sintang	Ketapang	Parit Baru FTP 1	Parit Baru FTP 2	Pantai Kura-Kura
PT Adaro Indonesia	892	533	660	660	703
PT Bara Multi Susksessarana	1,114	755	882	882	925
PT Borneo Indobara	898	538	666	666	709
PT Jorong Barutama Greston	834	475	602	602	645

Table 5: Coal Transportation Costs.

Mining Company	Transportation Costs from Mining Company to the PLTU (USD/ton)				
	Sintang	Ketapang	Parit Baru FTP 1	Parit Baru FTP 2	Pantai Kura-Kura
PT Adaro Indonesia	23.45	15.52	18.33	18.33	19.28
PT Bara Multi Susksessarana	28.36	20.43	23.23	23.23	24.18
PT Borneo Indobara	23.59	15.63	18.46	18.46	19.41
PT Jorong Barutama Greston	22.17	14.24	17.04	17.04	18.00

4.4 The Distance between Seaports of Mining Company and PLTU

Sales of coal are carried out free onboard on barges with different loading locations than loading on vessels. It is necessary to calculate the distance from the seaport of each mining company to each PLTU in West Kalimantan Province. The distance is calculated based on sea lanes that are traversed using Netpas software. The distribution of seaports PLTU and coal mining companies can be seen in Figure 1. It can be seen that the location of the PLTU is spread out in

Figure 1: The Distribution of PLTU and Coal Mining Companies.

West Kalimantan Province and the location of coal mining companies is spread outside the West Kalimantan Province. Then, the distance between the seaports of the mining companies and PLTU can be seen in the table 4.

Based on Table 4, the coal mining companies that have the closest distance to each PLTU is PT Jorong Barutama Greston. The furthest distance to each PLTU is PT Bara Multi Suksessarana. The farther the coal mining company is from the PLTU, the higher the cost of procuring coal.

4.5 Transportation Cost

The transportation used to transport coal from the mining company's seaport to the PLTU is a barge with size fewer than 30 feet. Coal transportation costs are calculated based on the distance from the coal company's seaport to the PLTU in the Nautical Mile (NM) unit. The calculation of these costs refers to the Regulation of the Directorate General of Mineral and Coal Number 644.K/30/DJB/2013 concerning the Procedure of Determining Coal Benchmark Prices. The cost of transporting coal using barges can be seen in table 5.

5 OPTIMIZATION MODEL

The establishment of an optimization model that will be achieved is minimizing the total cost of procuring coal for the PLTU. The objective function in forming the coal optimization model is based on the selling price and transportation costs of coal, with the X_{ij} variable as the amount of coal transported from the coal company to the PLTU. This is the objective function in the coal optimization model at the PLTU.

$$\text{Minimum Total Cost} = 52.32X_{11} + 44.39X_{12} + 47.20X_{13} + 47.20X_{14} + 48.15X_{15} + 57.05X_{21} + 49.11X_{22} + 51.92X_{23} + 51.92X_{24} + 52.87X_{25} + 66.14X_{31} + 58.18X_{32} + 61.01X_{33} + 61.01X_{34} + 61.96X_{35} + 56.70X_{41} + 48.77X_{42} + 51.57X_{43} + 51.57X_{44} + 52.52X_{45} \quad (4)$$

Constraint function is divided into two types: supply and demand. Demand constraints are based on the demand for coal to generate electricity in a year and supply constraints were limited by the company's coal production. The ffollowing are the functions of demand and supply constraints used.

Demand Constrains:

$$4{,}000X_{11} + 4{,}065X_{21} + 4{,}000X_{31} + 4{,}000X_{41} = 305{,}656{,}617 \quad (5)$$

$$4{,}000X_{12} + 4{,}065X_{22} + 4{,}000X_{32} + 4{,}000X_{42} = 145{,}550{,}769 \quad (6)$$

$$4{,}000X_{13} + 4{,}065X_{23} + 4{,}000X_{33} + 4{,}000X_{43} = 1{,}455{,}507{,}694.2 \quad (7)$$

$$4{,}000X_{14} + 4{,}065X_{24} + 4{,}000X_{34} + 4{,}000X_{44} = 1{,}455{,}507{,}694.2 \quad (8)$$

$$4{,}000X_{15} + 4{,}065X_{25} + 4{,}000X_{35} + 4{,}000X_{45} = 800{,}529{,}231.60 \quad (9)$$

Supply Constrains:

$$X_{11} + X_{12} + X_{13} + X_{14} + X_{15} \leq 50{,}601{,}101 \quad (10)$$

$$X_{21} + X_{22} + X_{23} + X_{24} + X_{25} \leq 1{,}500{,}000 \quad (11)$$

$$X_{31} + X_{32} + X_{33} + X_{34} + X_{35} \leq 4{,}003{,}273.74 \quad (12)$$

$$X_{41} + X_{42} + X_{43} + X_{44} + X_{45} \leq 203{,}887 \quad (13)$$

6 DISCUSSION

Based on the objective and constraint functions, the optimization problem is solved by WINQ SB software, so that the minimum coal procurement cost obtained at the PLTU is USD 2,565,963,000 in a year with the distribution of coal supply as the following table.

Based on these results, it is found that to obtain the most optimum coal procurement costs, coal input is required from various companies, where this is strongly influenced by the calorific value of coal, the selling price of coal, and the cost of coal transportation. Besides, the amount of coal demand and coal production capacity of mining companies are also the limits of the demand constrain and supply constrain functions. The coal demand at the Sintang PLTU can be supplied from PT Jorong Barutama Greston with 69,467.41 tons. The Ketapang PLTU can be supplied from 3 different mining company including PT. Adaro Indonesia with 50,601,100 tons, PT Bara Multi Susksessarana with 732,448.1 tons, and PT Borneo Indobara with 4,003,374. The Parit Baru FTP 1 PLTU can be supplied from PT Bara

Table 6: Variable Index.

Mining Company	Coal Supply from Mining Company to the PLTU (ton)				
	Sintang	Ketapang	Parit Baru FTP 1	Parit Baru FTP 2	Pantai Kura-Kura
PT Adaro Indonesia	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
PT Bara Multi Susksessarana	X_{21}	X_{22}	X_{23}	X_{24}	X_{25}
PT Borneo Indobara	X_{31}	X_{32}	X_{33}	X_{34}	X_{35}
PT Jorong Barutama Greston	X_{41}	X_{42}	X_{43}	X_{44}	X_{45}

Table 7: The Optimum Result.

Mining Company	Coal Supply from Mining Company to the PLTU (ton)				
	Sintang	Ketapang	Parit Baru FTP 1	Parit Baru FTP 2	Pantai Kura-Kura
PT Adaro Indonesia	-	50,601,100.0	-	-	-
PT Bara Multi Susksessarana	-	732,448.1	358,058.4	358,068.5	51,435.0
PT Borneo Indobara	-	4,003,374.0	-	-	-
PT Jorong Barutama Greston	69,467.4	-	-	-	134,419.5

Multi Susksessarana with 358,058.4 tons and Parit Baru FTP 2 PLTU can be supplied from PT Bara Multi Susksessarana as much as 358,068.5 ton. Pantai Kura-Kura PLTU can be supplied from 2 different mining company including PT Bara Multi Susksessarana with 51,435 tons and PT Jorong Barutama Greston with 134,419.5 tons.

7 CONCLUSION

The minimum cost of procuring coal for PLTU demands is USD 2,565,963,000 in a year with the following distribution of supplies: Sintang PLTU is supplied from PT Jorong Barutama Greston; Ketapang PLTU is supplied from PT. Adaro Indonesia, PT Bara Multi Susksessarana, and PT Borneo Indobara; Parit Baru FTP 1 PLTU supplied from PT Bara Multi Susksessarana; Parit Baru FTP 2 PLTU supplied from PT Bara Multi Susksessarana; The Kura-Kura PLTU is supplied from PT Bara Multi Susksessarana, and PT Jorong Barutama Greston.

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