Defining the Best LNG Supply Chain Scheme for Gasification of Sulawesi and Maluku Power Plants

Oktobyanto Raharjo* and Kuntoro Mangkusubroto

School of Business and Management, Institut Teknologi Bandung, Indonesia

Email: oktobyanto_raharjo@sbm-itb.ac.id

Abstract - **Gasification of Sulawesi and Maluku power plants is part of the MEMR Decree number 13 in 2020. Defining the best logistic scheme for this project by exploring all possible supply chains to get a suitable solution can be the key success factor of the project. It is challenging because there are seven power plants in the scattered area, with a gas demand of only 17,46 BBTUD for 288 MW power plants. The simulation by Python software examines 5,802 routes and 42 ships to determine the best option. By Python, the optimal logistics scheme uses the Bontang using one LNGC 17,500 m3. The best route is Badak NGL, PLTMG Baubau, PLTMG Kendari, PLTG Gorontalo, PLTMG Seram, PLTMG Ambon, PLTMG Namlea, PLTMG Ternate, and back to Badak NGL with a total distance of 2,664 NM, total CAPEX USD 160,798,153.34, total yearly OPEX USD 23,285,975.69, and NPV is USD 389,422,252.70. This project can make a portfolio of PT Gas in LNG better, especially on the small scale of LNG.**

Keywords - **CAPEX; gasification; LNG; LNGC; OPEX; optimal; and Python.**

I. INTRODUCTION

The Minister of Energy and Mineral Resources (MEMR) release Ministry Decree number 13 of 2020 has asked Pertamina to gasify in 52 power plants with the gas price limitation is HSD price. But from those numbers, only 30 power plants are ready now for gas conversion, where only three of them are in Sulawesi (Gorontalo, Kendari, and Baubau) and four in Maluku (Ambon, Ternate, Namlea, and Seram). The gas demand of Sulawesi Power Plants as Table 1 and Maluku Power Plants as Table 2.

This research purpose is to get the answer to the question "what is the suitable solution for gasification of Sulawesi and Maluku power plants?"

TABLE 1. THE SULAWESI POWER PLANTS GAS DEMAND

Cluster	Location	Coordinate		Powerplant	Capacity	Volume			
						KEPMEN 13	Average	Min	[illegible]
		Latitude	Longitude		MW	BBTUD	BBTUD	BBTUD	[illegible]
Sulawesi	Gorontalo	0°28'02.2"N	122°00'16.1"E	PLTG Maleo	100	17.52	5.30	4.64	[illegible]
	Kendari	3°53'47.20"S	122°32'21.01"E	PLTMG Nii Tanasa	59	7.48	2.68	2.10	[illegible]
	Bau-Bau	5°23'47.44"S	122°37'36.08"E	PLTMG Bau Bau	39	2.67	2.05	1.38	[illegible]
TOTAL					198	27.67	10.03	8.12	[illegible]

TABLE 2. THE MALUKU POWER PLANTS GAS DEMAND

Cluster	Location	Coordinate		Powerplant	Capacity	Volume			
						KEPMEN 13	Average	Min	Max
		Latitude	Longitude		MW	BBTUD	BBTUD	BBTUD	BBTUD
Maluku	Ternate	0° 45'59.71 N	127°18'22.49 E	MPP Ternate	30	2.75	3.07	2.23	3.79
	Ambon Peaker	3° 32'57.21 S	128°20'13.30 E	PLTMG Ambon Peaker	30	2.28	2.65	2.65	2.65
	Seram	3°18'21.17"S	128°56'46.42"E	PLTMG Seram	20	1.01	0.88	0.60	1.10
	Namlea	3° 13'51.37 N	127°6'30.74 E	PLTMG Namlea	10	0.85	0.83	0.66	0.98
TOTAL					90	6.89	7.43	6.14	8.52

II. METHODOLOGY

The research methodology has figured in a flow chart of Figure 1.

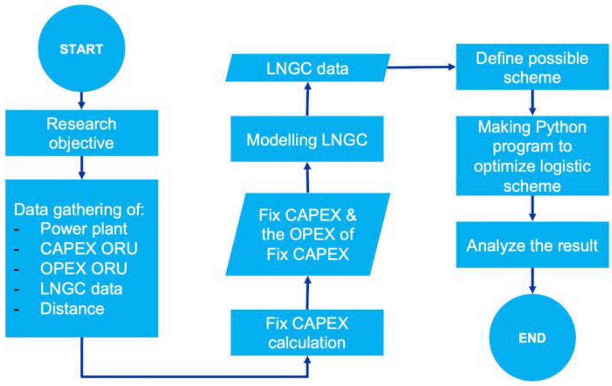

Figure 1. Flow chart of the research

TABLE 3. CAPITAL EXPENDITURE OF ORU (ANTARA, 2017)

No	System Name	Equipment	Unit	Unit Rate
1	LNG Transfer System	LNG Pump Skid	set	$ 900,000.00
		LNG Metering Unit	set	$ 2,300.00
		Cryogenic Line Pipe	m	$ 770.00
		Piping,valve,indicator,insulation,etc.	set	$ 225,768.00
2	LNG Storage System	LNG Storage Tank (ISO Container Tank)	m3	$ 2,000.00
		LNG Pump (RU Feeder)	set	$ 80,000.00
		Cryogenic Line Pipe	m	$ 770.00
		Piping,valve,indicator,insulation,etc.	set	$ 20,693.00
3	Regasification System	LNG Buffer Tank	set	$ 400,000.00
		Heat Exchanger (Ambient Air Type)	set	$ 120,000.00
		Gas Heater (steam)	set	$ 70,000.00
4	BOG Treatment	BOG Compressor	set	$ 700,000.00
		Piping,valve,indicator,insulation,etc.	set	$ 175,000.00
5	Gas Transfer System	Gas Heater (steam)	set	$ 70,000.00
		NG Line Pipe	m	$ 100.00
		Pigging (Launcher and Receiver)	set	$ 7,000.00
		NG Metering Unit	set	$ 1,500.00
		Piping,valve,indicator,insulation,etc.	set	$ 19,650.00
6	Electric Generator	Self-Driven Electric Generator (Diesel) sl	set	$ 1,200,000.00
7	Building and Office	Control Room	set	$ 20,000.00
		Office Building	set	$ 50,000.00
		Parking Area, Muster station, Utilization	set	$ 10,000.00
8	Fire Protection System	Hydrant pillar	set	$ 2,500.00
		Fire Alarm, Gas Detector	set	$ 5,000.00
		Portable Fire Distinguisher	set	$ 450.00
		Hydrant Pump	set	$ 2,500.00
9	Purging System	Nitrogen Storage Tank	set	$ 20,000.00
		Piping,valve,indicator,insulation,etc.	set	$ 2,000.00
10	Monitoring & Control	(Hardware & Software)	set	$ 800,000.00

The capital expenditure (CAPEX) is all investment costs to build all facilities in the Onshore Regasification Unit (ORU). Capital expenditures consist of jetty facilities, LNG offloading facilities, cryogenic pipe, LNG storage tank, LNG pump, vaporizer, BOG compressor, generator, supporting building and component installation (Antara, 2017). Operational expenditure (OPEX) is all the cost expenses that expend to support the operation of the LNG distribution. OPEX consists of the ORU and transportation cost to transport the LNG from the hub to the receiving facilities (Antara, 2017). The capital expenditure of the ORU is in Table 3.

Refer to Handbook of Liquified Natural Gas (Mokhatab, S, 2014), typical LNG receiving terminal schematic as seen in Figure2.

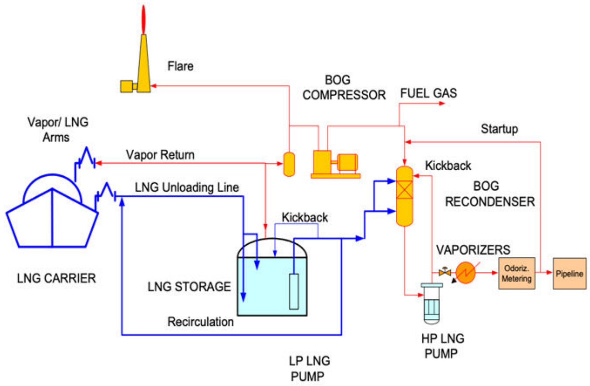

Figure 2. Typical LNG Receiving Terminal Schematic (Mokhatab S, 2014)

Refer to "(1)", CAPEX is consists of fixed CAPEX and variable CAPEX. CAPEX only in ORU. Variable CAPEX only for LNG Tank, the fix CAPEX for the other. CAPEX each ORU comes from Antara's data multiplied by the amount of equipment.

$$C_i = \sum N_i * P_i \qquad (1)$$

Where:
C_i = Total CAPEX in ORU I (USD per unit price)
N = Number of each equipment in ORU i (Unit)
P = Price of equipment in ORU I (USD)

TABLE 4. THE CAPITAL EXPENDITURE FOR ORU OF SULAWESI AND MALUKU POWER PLANTS

No	System Name	Equipment	Unit	Unit Rate		Ambon		PLTMG Baubau	PLTMG Nii Tanasa	PLTG Malea	PLTMG Ternate	PLTMG Namlea	PLTMG Seram
				Estimation Price		Hub Ambon	Hub Bontang	All Hub	All Hub	All Hub	All Hub	All Hub	All Hub
				2017	2021								
1	LNG Transfer System	LNG Pump Skid	set	$ 900,000.00	$ 992,700.00	$ -	$ 992,700.00	$ 992,700.00	$ 992,700.00	$ 992,700.00	$ 992,700.00	$ 992,700.00	$ 992,700.00
		LNG Metering Unit	set	$ 2,300.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
		Cryogenic Line Pipe	m	$ 770.00	$ 849.31	$ -	$ 392,381.22	$ 392,381.22	$ 373,866.40	$ 768,379.00	$ 459,627.40	$ 229,313.70	$ 348,207.10
		Piping,valve,indicator,insulation,	set	$ 225,768.00	$ 249,022.10	$ -	$ 249,022.10	$ 249,022.10	$ 249,022.10	$ 249,022.10	$ 249,022.10	$ 249,022.10	$ 249,022.10
2	LNG Storage System	LNG Storage Tank (ISO Container T	m3	$ 2,000.00	$ 2,206.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
		LNG Pump (RU Feeder)	set	$ 80,000.00	$ 88,240.00	$ -	$ 88,240.00	$ 88,240.00	$ 88,240.00	$ 88,240.00	$ 88,240.00	$ 88,240.00	$ 88,240.00
		Cryogenic Line Pipe	m	$ 770.00	$ 849.31	$ -	$ 42,465.50	$ 42,465.50	$ 42,465.50	$ 42,465.50	$ 42,465.50	$ 42,465.50	$ 42,465.50
		Piping,valve,indicator,insulation,	set	$ 20,693.00	$ 22,824.38	$ -	$ 22,824.38	$ 22,824.38	$ 22,824.38	$ 22,824.38	$ 22,824.38	$ 22,824.38	$ 22,824.38
3	Regasification System	LNG Buffer Tank	set	$ 400,000.00	$ 441,200.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
		Heat Exchanger (Ambient Air Type	set	$ 120,000.00	$ 132,360.00	$ -	$ 132,360.00	$ 132,360.00	$ 132,360.00	$ 132,360.00	$ 132,360.00	$ 132,360.00	$ 132,360.00
		Gas Heater (Steam)	set	$ 70,000.00	$ 77,210.00	$ -	$ -	$ -	$ -	$ 77,210.00	$ -	$ -	$ -
4	BOG Treatment	BOG Compressor	set	$ 700,000.00	$ 772,100.00	$ -	$ 772,100.00	$ 772,100.00	$ 772,100.00	$ 772,100.00	$ 772,100.00	$ 772,100.00	$ 772,100.00
		Piping,valve,indicator,insulation,	set	$ 175,000.00	$ 193,025.00	$ -	$ 193,025.00	$ 193,025.00	$ 193,025.00	$ 193,025.00	$ 193,025.00	$ 193,025.00	$ 193,025.00
5	Gas Transfer System	Gas Heater (Steam)	set	$ 70,000.00	$ 77,210.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
		NG Line Pipe	m	$ 100.00	$ 110.30	$ 19,854.00	$ 19,854.00	$ 19,854.00	$ 19,854.00	$ 19,854.00	$ 19,854.00	$ 19,854.00	$ 19,854.00
		Pigging (Launcher and Receiver)	set	$ 7,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
		NG Metering Unit	set	$ 1,500.00	$ 1,654.50	$ 1,654.50	$ 1,654.50	$ 1,654.50	$ 1,654.50	$ 1,654.50	$ 1,654.50	$ 1,654.50	$ 1,654.50
		Piping,valve,indicator,insulation,	set	$ 19,650.00	$ 21,673.95	$ 21,673.95	$ 21,673.95	$ 21,673.95	$ 21,673.95	$ 21,673.95	$ 21,673.95	$ 21,673.95	$ 21,673.95
6	Electric Generator	Self-Driven Electric Generator (Di	set	$1,200,000.00	$ 1,323,600.00	$ 1,323,600.00	$ 1,323,600.00	$ 1,323,600.00	$ 1,323,600.00	$ 1,323,600.00	$ 1,323,600.00	$ 1,323,600.00	$ 1,323,600.00
7	Building and Office	Control Room	set	$ 20,000.00	$ 22,060.00	$ 22,060.00	$ 22,060.00	$ 22,060.00	$ 22,060.00	$ 22,060.00	$ 22,060.00	$ 22,060.00	$ 22,060.00
		Office Building	set	$ 50,000.00	$ 55,150.00	$ 55,150.00	$ 55,150.00	$ 55,150.00	$ 55,150.00	$ 55,150.00	$ 55,150.00	$ 55,150.00	$ 55,150.00
		Parking Area, Muster station, Util	set	$ 10,000.00	$ 11,030.00	$ 11,030.00	$ 11,030.00	$ 11,030.00	$ 11,030.00	$ 11,030.00	$ 11,030.00	$ 11,030.00	$ 11,030.00
8	Fire Protection System	Hydrant pillar	set	$ 2,500.00	$ 2,757.50	$ 2,757.50	$ 2,757.50	$ 2,757.50	$ 2,757.50	$ 2,757.50	$ 2,757.50	$ 2,757.50	$ 2,757.50
		Fire Alarm, Gas Detector	set	$ 5,000.00	$ 5,515.00	$ 5,515.00	$ 5,515.00	$ 5,515.00	$ 5,515.00	$ 5,515.00	$ 5,515.00	$ 5,515.00	$ 5,515.00
		Portable Fire Distinguisher	set	$ 450.00	$ 496.35	$ 496.35	$ 496.35	$ 496.35	$ 496.35	$ 496.35	$ 496.35	$ 496.35	$ 496.35
		Hydrant Pump	set	$ 2,500.00	$ 133,333.33	$ 133,333.33	$ 133,333.33	$ 133,333.33	$ 133,333.33	$ 133,333.33	$ 133,333.33	$ 133,333.33	$ 133,333.33
9	Purging System	Nitrogen Storage Tank	set	$ 20,000.00	$ 22,060.00	$ 22,060.00	$ 22,060.00	$ 22,060.00	$ 22,060.00	$ 22,060.00	$ 22,060.00	$ 22,060.00	$ 22,060.00
		Piping,valve,indicator,insulation,	set	$ 2,000.00	$ 2,206.00	$ 2,206.00	$ 2,206.00	$ 2,206.00	$ 2,206.00	$ 2,206.00	$ 2,206.00	$ 2,206.00	$ 2,206.00
10	Monitoring & Control System	Process Control System (PCS), DCS (Hardware & Software)	set	$ 800,000.00	$ 882,400.00	$ 882,400.00	$ 882,400.00	$ 882,400.00	$ 882,400.00	$ 882,400.00	$ 882,400.00	$ 882,400.00	$ 882,400.00
11	Electrical System	Electrical Power System	set	$ 2,500.00	$ 266,666.67	$ 266,666.67	$ 266,666.67	$ 266,666.67	$ 266,666.67	$ 266,666.67	$ 266,666.67	$ 266,666.67	$ 266,666.67
12	ESD System	ESD System	set	$ 800,000.00	$ 882,400.00	$ 882,400.00	$ 882,400.00	$ 882,400.00	$ 882,400.00	$ 882,400.00	$ 882,400.00	$ 882,400.00	$ 882,400.00
13	LNG Hub				$ 145,000,000.00								
14	COST Marine Facilities			$ 41,188.00	$ 41,188.00	$ 6,631,268.00	$ 6,631,268.00	$ 6,631,268.00	$ 6,178,200.00	$ 15,651,440.00	$ 8,237,600.00	$ 2,677,220.00	$ 5,540,580.00
	Sub Total					$ 10,284,125.30	$ 13,169,243.50	$ 13,169,243.50	$ 12,697,490.68	$ 22,638,623.28	$ 14,841,821.48	$ 9,052,127.86	$ 12,054,160.38
	VAT 10%					$ 1,028,412.53	$ 1,316,924.35	$ 1,316,924.35	$ 1,269,749.07	$ 2,263,862.33	$ 1,484,182.17	$ 905,212.80	$ 1,205,416.14
	Total EPC					$ 11,312,537.83	$ 14,486,167.85	$ 14,486,167.85	$ 13,967,239.75	$ 24,902,485.61	$ 16,326,003.65	$ 9,957,340.78	$ 13,259,600.52
	OWNER COST				5%	$ 102,841.25	$ 658,462.18	$ 658,462.18	$ 634,874.53	$ 1,131,931.16	$ 742,091.08	$ 452,606.40	$ 602,708.57
	TOTAL FIXED CAPEX ORU					$ 11,415,379.08	$ 15,144,630.03	$ 15,144,630.03	$ 14,602,114.29	$ 26,034,416.78	$ 17,068,094.96	$ 10,409,947.18	$ 13,862,320.09
	TOTAL OPEX ORU/YEAR					$ 570,768.95	$ 757,231.50	$ 757,231.50	$ 730,105.71	$ 1,301,720.84	$ 853,404.75	$ 520,497.36	$ 693,116.00

CAPEX of ORU based on Table 3 and Figure 1 is in Table 4. CAPEX every path comes from the summary of the CAPEX ORUs. CAPEX every path equation refers to "(2)".

$$C_{px} = \sum C_{ix} \qquad (2)$$

Where:
C_{px} = Total CAPEX of path x (USD)
C_{ix} = Total CAPEX in ORU i for path x (USD)

The assumption of OPEX of ORU is 5%, according to the world bank report, 2015, state that: “In general, the OPEX of LNG importing facilities is estimated between 3 to 5% of the CAPEX”. The OPEX of ORU calculation refers to “(3)”. The total OPEX of every path to be “(4)”. The yearly fuel cost of LNGC comes from “(5)” and the yearly rental price of LNGC comes from “(6)”.

$$O_i = 5\%\ x\ C_i \tag{3}$$

Where:
O_i = Total OPEX in ORU i (USD)
C_i = Total CAPEX in ORU i (USD)

$$O_{px} = \sum O_{ix} + R_{ix} + F_{ix} \tag{4}$$

Where:
O_{px} = Total yearly OPEX of path x (USD)
O_{ix} = Total yearly OPEX in ORU i for path x (USD)
R_{ix} = Yearly rental price of LNGC i path x (USD)
F_{ix} = Fuel cost yearly of LNGC i path x (USD)

$$F_{ix} = F_d\ x\ F_p\ x\ D\ \ x\ 24.02 \tag{5}$$

Where:
F_{ix} = Yearly fuel cost of LNGC i path x (USD)
F_d = Daily fuel consumption (m3/day)
F_p = Fuel price (USD/MMBtu)
D = Total day in a year (365)

$$R_{ix} = \sum O_{ix} + R_p x\ D \tag{6}$$

Where:
R_{ix} = Yearlyrental priceof LNGC i path x
R_d = Daily rental price of LNGC (USD/day)
D = Total day in a year (365)

Based on the coordinate of the power plant locations, as seen in Tables 1 and 2, the sea distance can be measure by Netpas software. For the Hub, PLTMG Ambon will use FSRU Ambon as hub, so the Ambon Hub coordinate will be the same with PLTMG Ambon. For Badak NGL Hub, the coordinate will use the Badak NGL coordinate. Power plant distances come from theNetpas online software (Guide, U. 2015). The distance matrix is in Table 5.

Because of the limitation of those data, to LNGC assumption, the LNGC data using the Wartsila products (Wartsila, 2021), as shown in Table 6. The Wartsila Vessels Data, to develop the estimation of the size, gross weight and dimension, and fuel consumption of LNGC. The length of all (LOA) and the rental cost of LNGC will use the data of Antara, 2017, as shown in Table 7. LNG Storage Tank uses a Chart with 500 m3 capacity each.

TABLE 5. DISTANCE MATRIX (NM)

in nautical miles

Power Plant PLN	PLTG Maleo (Gorontalo)	PLTMG Nii Tanasa (Kendari)	PLTMG Baubau	PLTMG Ternate	PLTMG Seram	PLTMG Namlea	TMG Am	Badak NGL	Hub Ambon
PLTG Maleo (Gorontalo)		330	501	323	521	416	479	754	479
PLTMG Nii Tanasa (Kend	330		234	413	409	336	366	754	366
PLTMG Baubau	501	234		542	471	416	428	566	428
PLTMG Ternate	323	413	542		363	258	321	625	321
PLTMG Seram	521	409	471	363		128	44	933	44
PLTMG Namlea	416	336	416	258	128		86	829	86
PLTMG Ambon	479	366	428	321	44	86		890	
Badak NGL	754	754	566	625	933	829	890		890
Hub Ambon	479	366	428	321	44	86		890	

LNGC data is mandatory data to run the simulation. In this research, the LNGC sizes are from 2.500 m3 to 40.000 m3. The gas consumption and the gross tonnage (GT) are coming from the interpolation of Table 6. The length of all (LOA) and the rental cost of LNGC are coming from the interpolation of Table 7. The LNGC data from size 2.500 to 40.000 m3 by combining data from Table 6 and 7.

TABLE 6. THE WARTSILA VESSELS DATA (WARTSILA, 2021)

No	LNGC Size (m3)	Speed (knots)	Gas consumption (ton/day)	LOA (m)	Deadweight (DWT)	Gross Tonnage (GT)
1	3,000	12.0	7.5	84.7	2,000.0	3,900.0
2	5,000	14.0	11.9	99.9	3,000.0	
3	6,500	13.0	9.8	98.8	4,200.0	
4	7,500	13.5	8.4	115.1	4,100.0	6,850.0
5	10,000	14.0	12.1	124.9	7,200.0	
6	12,000	14.5	13.5	137.0	9,900.0	12,300.0
7	20,000	15.0	18.1	147.3	12,500.0	17,270.0
8	30,000	16.0	25.1	170.0	15,000.0	

TABLE 7. THE LENGTH OF ALL (LOA) AND RENTAL COST OF LNGC (ANTARA, 2017)

No	Parameter	Unit	LNG Carrier			
1	Capacity	m3	2,500	7,500	10,000	23,000
2	LOA	m	86.25	117.80		151.00
3	Breadth	m	15.10	18.60	20.00	28.00
4	Draft	m	3.80	7.15	7.10	8.00
5	Speed	Knot	13.00	14.00	14.00	15.00
6	Rental price	USD/day	$ 18,000.00	$ 25,000.00	$30,000.00	$40,000.00
7	Fuel Consumption	t/day	7.90	11.00	16.00	19.70

From 2,500 m3 until 20.000 m3, the size of LNGC for the simulation is gradually every 500 m3 to get the optimum size of LNGC. From 20,000 m3 until 30,000 m3, the gradual changes to be 2,500 m3. After 30,000 m3, the gradual change again to 5,000 m3. The total LNGC for the simulation is 42 sizes, as shown in Table 8.The data processing will use the data both manually and automatically. Manual processes analysis executed by Microsoft Excel and the automatic process using the Python version 3.9.5 software (Manual, 2021).

The best logistic scheme comes from hub comparison, optimization of LNGC for all possible logistic routes, and LNGC configuration. The vessel for cluster Sulawesi and Maluku can have one or two LNGCs. All possible schemes are in Figure3.

TABLE 8. THE LNGC GENERATED DATA

No	LNGC Carrier Size	Gas consumption (ton/hari)	Gas consumption (m3/hari)	Daily Rent (USD)	GT (tonne)	LOA (m)
1	2,500	7.5	16.62	$ 17,804.75	3501.5	79.9
2	3,000	7.8	17.28	$ 18,706.30	3906.3	84.5
3	3,500	9.8	21.78	$ 19,592.85	4311.2	88.6
4	4,000	8.4	18.62	$ 20,464.40	4716.0	92.3
5	4,500	8.7	19.28	$ 21,320.95	5120.9	95.7
6	5,000	9.0	19.95	$ 22,162.50	5525.7	98.9
7	5,500	9.3	20.62	$ 22,989.05	5930.6	101.8
8	6,000	9.6	21.28	$ 23,800.60	6335.4	104.5
9	6,500	9.8	21.78	$ 24,597.15	6740.3	107.1
10	7,000	10.2	22.62	$ 25,378.70	7145.1	109.6
11	7,500	10.5	23.28	$ 26,145.25	7550.0	112.0
12	8,000	10.8	23.95	$ 26,896.80	7954.8	114.2
13	8,500	11.1	24.62	$ 27,633.35	8359.7	116.3
14	9,000	11.4	25.28	$ 28,354.90	8764.5	118.4
15	9,500	11.7	25.95	$ 29,061.45	9169.4	120.4
16	10,000	12.3	27.28	$ 29,753.00	9574.2	122.3
17	10,500	12.3	27.28	$ 30,429.55	9979.1	124.1
18	11,000	12.6	27.95	$ 31,091.10	10383.9	125.9
19	11,500	12.9	28.62	$ 31,737.65	10788.8	127.7
20	12,000	13.5	30.00	$ 32,369.20	11193.6	129.3
21	12,500	13.5	29.95	$ 32,985.75	11598.5	131.0
22	13,000	13.8	30.62	$ 33,587.30	12003.3	132.6
23	13,500	14.1	31.28	$ 34,173.85	12408.2	134.1
24	14,000	14.4	31.95	$ 34,745.40	12813.0	135.6
25	14,500	14.7	32.62	$ 35,301.95	13217.9	137.1
26	15,000	15.0	33.28	$ 35,843.50	13622.7	138.5
27	15,500	15.3	33.95	$ 36,370.05	14027.6	139.9
28	16,000	15.6	34.62	$ 36,881.60	14432.4	141.3
29	16,500	15.9	35.28	$ 37,378.15	14837.3	142.6
30	17,000	16.2	35.95	$ 37,859.70	15242.1	143.9
31	17,500	16.5	36.62	$ 38,326.25	15647.0	145.2
32	18,000	16.8	37.28	$ 38,777.80	16051.8	146.5
33	18,500	17.1	37.95	$ 39,214.35	16456.7	147.7
34	19,000	17.4	38.62	$ 39,635.90	16861.5	148.9
35	19,500	17.7	39.28	$ 40,042.45	17266.4	150.1
36	20,000	18.0	39.95	$ 40,434.00	17671.2	151.3
37	22,500	19.5	43.28	$ 42,166.75	19695.5	156.9
38	25,000	21.0	46.62	$ 43,524.50	21719.7	162.0
39	27,500	22.5	49.95	$ 44,507.25	23744.0	166.8
40	30,000	24.0	53.28	$ 45,115.00	25768.2	171.3
41	35,000	27.0	59.95	$ 45,205.50	29816.7	179.7
42	40,000	30.0	66.62	$ 43,796.00	33865.2	187.2

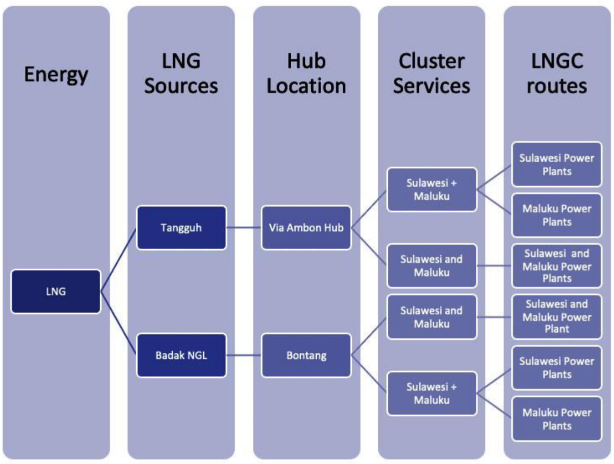

Figure 3. All possible schemes in gasification Sulawesi and Maluku power plants

The NPV of 20 years projects comes from the calculation of the total CAPEX and yearly OPEX. Since the total of yearly OPEX is annual the same value during the project, the net present value (NPV) of the total OPEX refers to be "(7)".

$$NPV_x = O_{px}[\ (1 + r)^{\,n-1}\ ] / [\ r\,(1 + r)^{\,n}\ ] \qquad (7)$$

Where:
NPV_x = NPV of OPEX for logistic scheme path x
O_{px} = Total yearly OPEX of path x
r = Interest rate
n = number of year

The NPV of each path gets from the total capital expenditure added with the present value of the total OPEX, refer to "(8)".

$$NPV_{tx} = NPV_x + C_{px} \qquad (8)$$

Where:
NPV_{tx} = NPV total for logistic scheme path x
NPV_x= NPV of OPEX for logistic scheme path x
C_{px} = Total CAPEX of path x

To check the availability of the route using 42 LNGCs. Then, it will be simulated automatically using Python software. The flowchart is in Figure4.

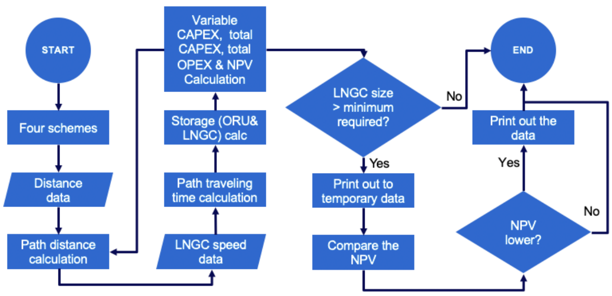

Figure 4. Flow chart of logistic scheme simulation

In running Python, power plants and potential hubs shall be index. The index of the power plant and hub is in Table 9.

TABLE 9. INDEX OF POWER PLANTS AND POTENTIAN HUBS

Index No	Power Plant PLN
0	PLTG Maleo
1	PLTMG Nii Tanasa
2	PLTMG Baubau
3	PLTMG Ternate
4	PLTMG Seram
5	PLTMG Namlea
6	Ambon
8	Badak NGL
9	Hub Ambon

III. RESULTS

ISBN*: 978-623-92201-2-9*

Route selection is generated automatically by the program with the lowest NPV as cost value. The principal is to maximize the profit or to meet the HSD price at the plant gate. The simulation contains 5,802 possible routes multiplied by 42 LNGC with come 243,484 simulations. The program result of the best route is in Figure5.

```
Speed = 10
Speed = 10
Speed = 10
The most optimum route is (8, 2, 1, 0, 4, 6, 5, 3, 8) with distances 2664 NM, using the one vessel (no. 31)
```

Figure 5. The program result of the best route

Based on Figure5, the best scheme is the 3rd scheme, toservegasificationSulawesiandMalukupowerplantfromBontanghubusing a single LNGC (no. 31), with the route (8,2,1,0,4,6,5,3,8) with a distance of 2,664 NM. Itmeans, the sequence of route or path is Badak NGL, PLTMG Baubau, PLTMG NiiTanasa (Kendari), PLTG Maleo (Gorontalo), PLTMG Seram, PLTMG Ambon, PLTMG Namlea, PLTMG Ternate and back to Badak NGL, as seen in Figure6.

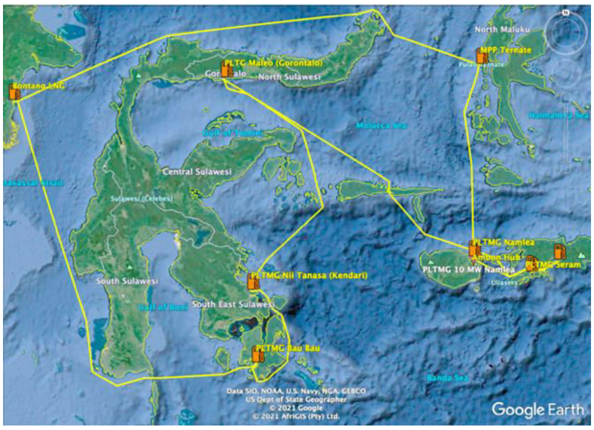

Figure 6. Route selected of Sulawesi and Maluku power plant

The selected route has the smallest distance, 2,664 NM, and optimum LNGC, with Vessel number 31st, as code refers to Table 8 is 17,500 m3. It means the smallest LNGC will not always be selected because the LNGC shall meet the minimum capacity to bring LNG to some areas with the minimum for the trip duration multiplied with the total volume of the served. When the minimum size of LNGC is not meet, there will not be considered as choices, even though less NPV, because the supply chain shall be reliable.

Total CAPEX for the selected route is USD 160,798,153.34, total yearly OPEX USD 23,285,975.69, and NPV for 20 years is USD 389,422,252.70.

IV. DISCUSSION

The jetty length can be optimized when the draught LNGC and sea data are available. In this assumption, the jetty length in all areas defines manually to serve LNGC with 10 m draughts because the sea data are not available.

The LNGC speed is assumed 10 knots due to sea wave data is not available. Faster LNGC speed will result in the same route, with a smaller LNGC size, effect cost reduction. But, the speed also will consider the fuel consumption, due to the fuel as cost function.

V. CONCLUSION

1. The best logistic scheme using LNG Badak NGL to serve Sulawesi and Maluku power plants using one LNGC LNGC 17.500 m3 through route Badak NGL, PLTMG Baubau, PLTMG NiiTanasa (Kendari), PLTG Maleo (Gorontalo), PLTMG Seram, PLTMG Ambon, PLTMG Namlea, PLTMG Ternate and back to Badak NGL with distance 2.664 NM, total CAPEX USD 160,798,153.34, total yearly OPEX USD 23,285,975.69, and NPV are USD 389,422,252.70.

2. Ambon hub price will significantly increase the CAPEX and OPEX of the logistic scheme from Ambon hub rather than Bontang. Higher CAPEX can not be compensated enough by the closer distance of the Ambon hub to the Sulawesi and Maluku power plants because the total demand is small.

ACKNOWLEDGMENT

We thank Prof. DR. KuntoroMangkusubroto for providing coach of final project; we thank all SBM ITB lecturers for the knowledge and support; we thank Adam Nur Bawono and BayuLambangPamungkas for the data and support; we thank to Putrisia HA,M. HafizhAbdulmuhsin, M. Ihsan Abdurrahman, AisyahQanita A, my parents, and my family for the support; we thank Al Farisi for the support and coach.

REFERENCES

[1] Antara, G.B.D.S., 2017. Optimasi Dan Analisa KeekonomianDistribusi LNG KePembangkit Di Wilayah Papua (Doctoral dissertation, InstitutTeknologiSepuluhNopember).

[2] Budiyanto MA, Pamitran AS, Yusman T. Optimization of the route of distribution of LNG using small scale LNG carrier: a case study of a gas power plant in the Sumatra region, Indonesia. International Journal of Energy Economics and Policy. 2019;9(6):179-87.

[3] Guide, U. (2015), User Guide Netpas Distance WebService. Available from: https://www.netpas.net/assets/files/download/WebService_ UserGuide3.03.pdf.

[4] Harperscheidt, 2011 Cost estimates along the LNG bunkering value.

[5] Higgins, R., 2011. Analysis for Financial Management, 10e. Burr Ridge: McGraw-Hill.

[6] IGU World LNG Report 2019: https://www.igu.org/app/uploads-wp/2019/06/IGU-Annual-Report-2019_23.pdf.

[7] Manual, 2021, https://docs.python.org/3/download.html.

[8] Maulana MA, Kurniawan F. Operational Risk Assessment Of Ship To Ship Transfer In The FSRU Lampung Using Risk Matrix Method. In IOP Conference Series: Earth and Environmental

Science 2020 Aug 1 (Vol. 557, No. 1, p. 012035). IOP Publishing.
[9] Mokhatab S, Mak JY, Valappil JV, Wood DA.Handbook of liquefied natural gas. Gulf Professional Publishing; 2013 Oct 15.
[10] The Minister of Energy and Mineral Resources (MOEMR) respond the president instruction by MOEMR Decree No. 13 of 2020 https://jdih.esdm.go.id/index.php/web/result/2116/detail.
[11] Tangguh Towuti Data https://www.marinetraffic.com/en/ais/details/ships/shipid:725954/mmsi:563214000/imo:9325893/vessel:TANGGUH_TOWUTI.
[12] Wartsila, 2021: https://www.wartsila.com/marine/build/ship-design/merchant/gas-carriers.
[13] Mini and Micro LNG for Commercialization of Small Volumes of Associated Gas. Tractebel Engineering, 2015. URL: https://openknowledge.worldbank.org/handle/10986/25919 (date of access 04.01.2021)