Financial and Economic Viability of Pumped Storage to Strengthen the VRE Development in Indonesia

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ABSTRACT
Pumped Storage Power Plant (PSP) is a new technology in Indonesia and will be installed to provide peak power to the grid. The existing power plant used by Perusahaan Listrik Negara (PLN) to provide this peaking power in Java-Bali Grid system is Gas Fired Power Plant (GFP) that uses Compressed Natural Gas (CNG) fuel to generate electricity. The purpose of this study is to evaluate the viability of PSP to displace GFP in economic and financial terms with selected cases from Upper Cisokan and Matenggeng. Three different approaches were performed to unfold the economic viability of PSP projects from long-term, mid-term, and classical simplified economic analysis with avoided cost models. The results show that the project is viable for all the analysed cases. These results support PLN's objective to absorb variable renewable power generation in an environmentally sustainable way and strengthen PLN capacity to support the development of new renewable energy.

Keywords: *Pumped Storage, Environmental Economics, Renewable Energy, Cost-Benefit Analysis.*

1. INTRODUCTION

The Indonesia government has recently announced that old fossil fuel power plants will be replaced by renewable energy. A new Presidential Regulation has been prepared by the MEMR to expedite investment in renewable energy to achieve 23% of renewable energy capacity in the country by 2025. It is better to prioritize a combination of pump storage with variable renewable energy (VRE), such as solar and wind since they are free and cheaper. Investing in VRE projects should be a better option for the Government since there has been a sharp decrease in the demand of electricity due to the COVID-19 pandemic.

Perusahaan Listrik Negara (PLN), has engaged in a massive development of the high cost Coal Fired Power Plants (CFP) while ASEAN neighbours have managed to double their installed renewable capacity [1]. Considering the recent low electricity demand and modest economic growth forecast for Indonesia, a combination of renewable energy sources (such as solar and wind) and storage solutions (such as pump storage and battery) could prove to be more desirable.

PLN over-reliance on CFP is the systemic problems in the Java-Bali grid that had resulted in the most expensive and longest blackout ever in Indonesia in 2019. Externalities of coal are another cost that is often left out, which include not only water and air pollution, but also other environmental issues due to its high carbon intensity.

S&P and Moody's are now forecasting a very little window of opportunity for gas projects to compete efficiently and effectively against VRE [2]. Investment in gas infrastructure is long-term, and gas pipelines generally need Capital Expenditure (CAPEX) renewal or maintenance cost of at least 20 to 30 years to generate a profit, while during that period gas might no longer be a cost-competitive source of peaking power. Pump storage and battery paired with VRE could provide peaking power with less volatility and lower marginal cost, thus supporting grid investment without an increase in tariff.

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This option will be the consumer's preferred choice since they will be able to enjoy price reduction.

The COVID-19 pandemic has a dramatic impact on PLN, this means power demand has fallen sharply due to the large-scale social restriction (PPKM). Large falls in demand due to COVID-19 will aggravate a high cost mismatch with new IPP supply for PLN. The addition of 7,365 MW of CFP IPP in coming years will cause oversupply in the Java-Bali grid. This development has worsened the PLN financial stress, PLN has already been struggling in 2020 to maintain a 41.5% reserve margin in Java-Bali alone.

PLN financial health is heavily reliant on growing subsidies from the government and now is under stress due to power purchased payment to IPP. PLN is now exposed to inflexible payment obligation, since most power purchasing agreements (PPA) include rigid capacity payment obligation that PLN shall pay to IPP whether or not PLN needs the power. PLN is struggling to reconcile its subsidy relief with the cost of IPP capacity expansion with COVID-19 downturn. This financial stress is the direct impact from having an overestimated demand growth consistently.

Therefore, it would be important for PLN to suspend any IPP negotiation, particularly which will add unnecessary capacity to the grid. Reducing expenditures by suspending unnecessary fossil fuel generation projects is a good starting point to protect PLN's financial position from getting worse. PLN needs government support to make sure that PLN can cancel projects that are not needed, in addition to capital injection, subsidies and compensation.

Many countries have started their power transformations by adapting their power system infrastructure to accommodate new technology in storage options (pump storage and battery), VRE technology and smart grid. They were transformed from overreliance on inflexible CFP baseload to cost-effective modular solutions that VRE can provide. The Indonesia power sector should find a new and cleaner technology option to stay competitive with its regional competitors. This Covid-19 Pandemic would be a catalyst for further financial innovation and new technologies.

Pumped Storage is a solution from PLN to provide a reliable and an inexpensive peak power generation to the Java-Bali grid system. Three Pumped Storages planned by PLN target to begin their Commercial Operation Date (COD) in 2024-2026, which are Upper Cisokan, Matenggeng, and Grindulu. The role of Pumped Storage Power Plant (PSP) is vital to overcome the intermittency problem of planned VRE, such as Solar and Wind [3]. The objective of PSP in the Java-Bali grid system is to increase the peaking power capacity in an environmentally and socially sustainable way by generating affordable electricity. The basic idea is to replace power from the GFP with Hydro Power Plant (HP) during the peak hour.

Upper Cisokan will be the first PSP in Indonesia, which will be followed by Matenggeng. However, delays in the development of the Upper Cisokan PSP project have caused the International Bank for Reconstruction and Development (IBRD) to cancel part of their loans in 2017. This loan agreement, effective since 2012, was planned to fund the Upper Cisokan PSP project and the Matenggeng PSP project. Hence, to start the commencement of this project, a new loan is needed to finance the Upper Cisokan PSP project. Thus, to proceed with the new loan, a present analysis of the Upper Cisokan PSP project is needed, since the previous economic and financial analysis are outdated and need to be updated with the latest economic parameters.

2. METHOD

2.1. Project Location

The Upper Cisokan PSP (UCPSP) is located at two administrative districts in West Java Province, which are Cianjur and West Bandung regency, and around 40 km west from Bandung city, while Matenggeng PSP (MPSP) is located in the middle of Java Island.

PSP will require two reservoirs (upper and lower) that can be made by building two Dams. The difference between the heights of each reservoir, called net head, is used by the PSP system to produce its own installed capacity. The upper and lower reservoir of both UCPSP and MPSP will be connected by an underground waterway, and the water will flow-through the waterway daily due to the characteristics of the PSP system that use the same water storage.

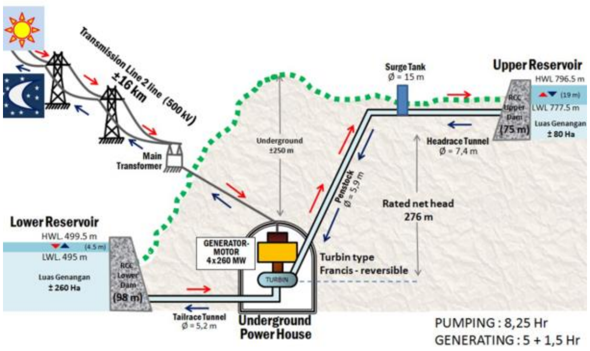

Figure 1 the Operating Pattern of UCPSP

The principle of the operating pattern of UCPSP is shown in Figure 1, the upper reservoir is used to store electricity during empty hours to provide electricity at peak hour. PSP will use low cost electricity to pump the water during empty hours (00:00-08:00). In addition, during peak hours (17:00-23:00), PSP will provide peak power by generating electricity to the Java-Bali Grid system. The advantage of PSP is its capability to store unused electricity.

In combination with VRE, PSP will store unused energy from VRE and use only when needed, thus strengthening the VRE integration in Indonesia. PSP's latest task is to support the VRE power plant, since power energy from wind [4] and solar 5] are uncertain and cannot be regulated. Therefore, the utilization of free, rich and sustainable electricity from solar and wind will increase sharply.

2.2. Data Analysis

The economic analysis of the PSP project can be estimated in three different but complementary approaches, which are first, simplified economic analysis with avoided cost model; second, the mid-term economic analysis in the context of load dispatching energy, and third, the long-term economic analysis of the project in the context of Electricity Supply Business Plan (RUPTL).

2.2.1. Simplified Economic Analysis with Avoided Cost Model

The purpose of the economic analysis is to evaluate the economic viability of the PSP project by comparing the projected operating results of the current project (PSP) with the alternative power plants (GFP). The Economic Internal Rate of Return (EIRR) equation in evaluating the economic viability of the project is calculated as follows:

$$EIRR = r\ (\%) \qquad (1)$$

Derived from the following formula

$$\sum_{t=0}^{n} \frac{C_t}{(1+r)^t} = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} \qquad (2)$$

The calculation of Cost-Benefit ratio is proposed in this methodology according to the following equation:

$$\frac{B}{C} = \frac{[Capacity\_Credit] + [Fuel\_Cost\_Saving]}{[Capital\_Cost\_PSP]} \qquad (3)$$

2.2.2. Discount Rate

Social Discount Rates based on the Ramsey formula [4] below can be used:

$$r = \delta + \gamma g \qquad (4)$$

IBRD setting are $\delta = 0$, $\gamma = 2$ therefore $r = 2g$. Social Discount Rate yields approximately 10% discount rate from 5.17% of Indonesia growth in 2018. The PSP project can be stated as economically viable, if the EIRR derived from the above equation exceeds the real opportunity cost, which is 10% in this case.

3. RESULT AND DISCUSSION

The economic analysis of the PSP project can be estimated in three different but complementary approaches, which are first, simplified economic analysis with avoided cost model; second, the mid-term economic analysis in the context of load dispatching energy, and third, the long-term economic analysis of the project in the context of Electricity Supply Business Plan (RUPTL).

3.1. Simplified Economic Analysis

The main output for the avoided cost model of economic analysis is summarized in Table 1. Both the Upper Cisokan PSP and Matenggeng PSP B/C ratio are higher than 1.00, therefore, the PSP is preferred to the GFP as the alternative thermal plant.

Table 1 the Results of Avoided Cost Model of Economic Analysis

Results	Upper Cisokan PSP	Matenggeng PSP
EIRR	16.38%	12.53%
NPV	$ 466.20 Million	$ 156.97 Million
B/C Ratio	1.51	1.22
Net Benefit	9.60 $/kW/year	4.37 $/kW/year

3.2. Monte Carlo Simulation Analysis

A probabilistic approach of Monte Carlo Simulation Analysis method has been applied to the model to provide additional assessment on the confidence level of economic analysis of the project. The Normal (Gauss or Gaussian) distribution is used to capture uncertainty in the input data and model parameters [6]. Monte Carlo simulation with a total of 1,000 iterations, have been performed with randomly generated set values for each iteration from the probability distribution. The results of Monte Carlo simulations for both PSP projects are shown in the Figure 2 to Figure 5.

3.3. Mid-Term Economic Analysis using JROS

JROS by Siemens Company simulates the system mid-term dispatching strategy on an hourly basis to provide the pumping and generating hours and the cost of the energy for the period of analysis. The purpose of the JROS simulation was to update the models with the information from RUPTL 2018-2027 and to verify that it supports the results of simplified economic analysis in the sense that PSP is preferred to GFP.

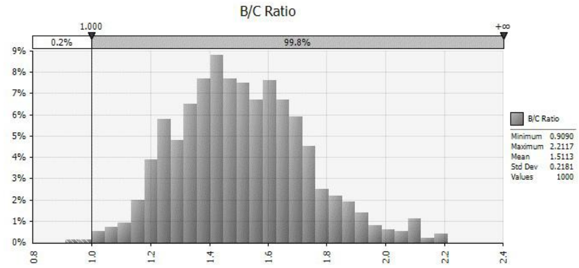

Figure 2 B/C ratio of UCPSP in relative frequency distributions

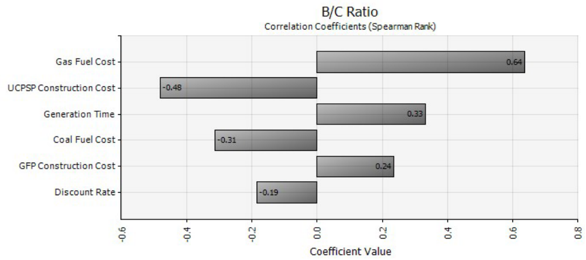

Figure 3 Influence of the Model Parameters to the Results of UCPSP B/C Ratio

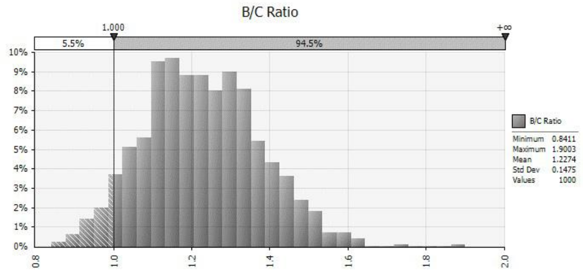

Figure 4 B/C ratio of MPSP with relative frequency distributions

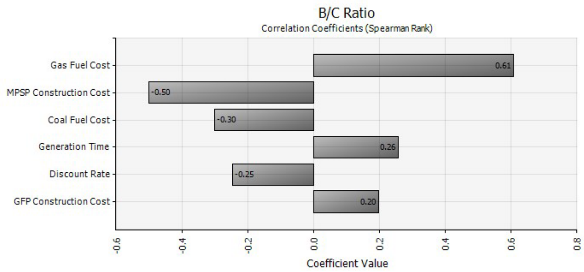

Figure 5 Influence of the Model Parameters to the Results of MPSP B/C Ratio

The conclusion derived from JROS simulation is that PSP is compatible with the dispatching strategy of Java-Bali and leads to lower cost of dispatching when compared to GFP as an alternative thermal plant in Java-Bali Grid system.

3.4. Long-Term Economic Analysis using WASP

PLN adopted Wien Automatic System Planning (WASP) to evaluate PSP project role in the generation portfolio of Indonesia from an economical point of view. Since National Grid data are sensitive, and have restrictions for accessibility, this simulation should be performed by PLN. WASP packages, previously developed by Tennessee Valley Authority in 1972, are now available via IAEA with the latest release of WASP version IV.

The WASP simulation for system expansion in 2018-2034 accepts implementing PSP, showing its potential feasibility and benefits with the fact that the total cost of the system expansion policy is smaller than without utilizing PSP. The results also support the simplified economic analysis based on the classical avoided cost model, proving that PSP is preferred over GFP.

To refinance the UCPSP project loans from the Development Bank are the most suitable way, as funding sources, to refinance the project. UCPSP will be co-financed between IBRD and the Government of Republic of Indonesia through PLN with 70% of debt and 30% of equity during construction. Grace period is three years with 15 years of Maturity period.

3.5. Condition and Method of Evaluations

Since PLN uses both debt and equity to finance the project, the Weighted Average Cost of Capital are used, which stated to be [7]:

$$R_{WACC} = \frac{S}{S+B} \times R_S + \frac{B}{B+S} \times R_B \times (1 - t_C) \quad (5)$$

IBRD discount rates (3.91%) can be derived from the average of London Interbank Offered Rate (LIBOR) for period 1999-2018 (2.21%) (Global-Rates.com 2019) plus credit spread (1.7%). Taking into account that PLN cost of equity is 12%, and tax rate is 25%, the RWACC results to be 5.65%.

CAPEX should include 10% VAT and 4% Withholding Tax as base cost for the analysis. In addition, price escalation of 4.77% for local currency and 1.80% for foreign currency based on CPI of Indonesia [8] and US [9] in the last 10 years, also applied to the base CAPEX.

Mainly, PSP projects can be completed in a six-year duration with one unit starting the COD. In the 7th year all units will start the COD. IDC in this case uses the same cost of debt. In this Financial Analysis, Revenues is the ascending tariff, which is the most common, with a peak factor of 1.3 according to the European energy market [10].

Since the average electricity selling price from PLN in 2018 is Rp 1,127/kWh [11], the resulting tariff of Rp 1,465/kWh is used in the analysis. This tariff is still higher than average electricity production cost of PLN in 2018, which is Rp 1,406/kWh [11]. Finally, tariff escalation of 2%, from the increase of PLN average selling price from 2017 to 2018, is applied throughout the project life.

According to the PLN's best practice for Hydropower projects, a 3.30% of annual depreciation is applied. The annual O&M costs are based on the percentages of CAPEX, which are 0.50% for civil works and 1.50% for permanent equipment. A 1.80% inflation is applied to the O&M cost. Income taxes are assumed to be 25% of EBT. IBRD loan is assumed to cover the requirement of foreign currency with its exchange risk taken by the Government.

In this analysis, one financial index that could serve as an indication of the ability to meet the future of debt service obligation is Debt Service Coverage Ratio (DSCR) [12]. According to PLN, the minimum value of 1.5 times DSCR is accepted In this case, DSCR is defined as follows:

$$DSCR = \frac{\text{Cash From Operations availabe for Debt Service}}{\text{Debt Service (Principal Repayment + Interest payment)}} \quad (6)$$

Financial Internal Rate of Return (FIRR) measures the prospective return of internally funded project capital costs, similar to the EIRR but substituting costs and benefits expressed in financial terms, defined as follows:

$$\text{FIRR} = r\ (\%) \quad (7)$$

Derived from the following formula,

$$\sum_{t=0}^{n} \frac{C_t}{(1+r)^t} = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} \quad (8)$$

Where,

C_t = Financial Cost (Principal + Repayment Self-Funded Construction and Financial Costs)
B_t = Financial Profit (Depreciation + Net Income)
t =year
n =book life of project (years)
r =RWACC (%)

3.6. The Result of Financial Analysis

The results from financial analysis showed the viability of the UCPSP project. Table 2 summarized the result of financial analysis for the base case.

3.7. Sensitivity Analysis for Financial Analysis

Sensitivity analysis has been performed with different values of variable or model parameters, which are construction costs, the addition of pumping costs, debt-equity ratio, interest rate, energy production, construction period, and exchange rates. The project is financially viable for all the case with the results shows that project $F_{IRR} > R_{WACC}$, NPV >0, and the average.

4. CONCLUSION

The results from economic analysis show that PSP is very attractive. The electricity master plan for the period 2019-2034 accepts the implementation of PSP showing its viability and benefits. WASP and JROS results support the results from simplified economic analysis based on avoided cost models, in the sense that PSP is preferred over GFP. Monte Carlo Simulation further confirms this economic analysis.

From the financial analysis point of view, UCPSP projects are viable with Financial IRR and DSCR that are higher than the accepted minimum value. Even with the increase of construction cost, the project will still yield high benefits. The lowest result from the sensitivity case is with an increase of 4% exchange rate per year with compounded growth. Even with this condition, PLN still yields high benefits with $653 million of NPV, 9.9% of Financial IRR>5.65% (WACC), and Average DSCR is 2.6.

PLN should promptly develop PSP to provide its benefits not only for the financial benefit of the company, but also for the Indonesian economy. PSP clearly supports PLN strategies to reduce the cost of electricity production and realize affordable electricity tariffs for consumers, thus reducing subsidies from the government. PSP will also add reliability to the Java-Bali grid system in the worst-case event of blackout. In terms of sustainable energy campaign, PSP will support the future optimization of potential Wind and Solar energy by solving its intermittency problems, and displaced gas fuel that is not environmentally sustainable. By Developing the Upper Cisokan and Matenggeng PSP, PLN will avoid the utilization of approximately 2 GW of GFP in the future and substitute it with PSP. In addition, this also will imply the substitution of 2 GW of CFP or Coal and change it with VRE.

AUTHORS' CONTRIBUTIONS

K.H. and P.N.C. conceived the presented idea. K.H. collected data and performed the analysis. A.D.P. and P.N.C. verified the analytical method and supervised the calculation and results. K.H. wrote the manuscript with support and supervision form P.N.C.

REFERENCES

[1] E. Hamdi, Racing Towards 23% Renewable: FIT to Start, but New Policies to Support Competition Are the Key to Indonesia's Renewables Future. Information and educational purposes, Lakewood: The Institute for Energy Economics and Financial Analysis (IEEFA), 2020.

[2] M. Brown, Running Out of Options: Six Questions for PLN. Information and educational purposes, Lakewood: The Institute for Energy Economics and Financial Analysis (IEEFA), 2020

[3] Ela, E., B. Kirby, A. Botterud, C. Milostan, I. Krad, and V. Koritarov. 2013. "The Role of Pumped Storage Hydro Resources in Electricity Markets and System Operation." HydroVision International. Denver: National Renewable Energy Laboratory. 1-10.

[4] J. Dhillon, A Kumar, and S.K. Singal, A stochastic approach for the operation of a wind and pumped storage plant under a deregulated environment." International Journal of Green Energy (Taylor & Francis) 55-62, 2016

[5] M. Belouda, H. Oueslati, S.B. Mabrouk, A. Mami. 2019. "Optimal design and sensitivity analysis of a PV-WT-hydraulic storage system generation in a remote area in Tunisia." Energy Sources, Part A: Recovery, Utilization, and Environmental Effects (Taylor & Francis) 1-15.

[6] F.P. Ramsey, A Mathematical Theory of Saving." The Economic Journal (Blackwell Publishing for the Royal Economic Society) 38 (152): 543-559. Accessed 12 09, 2010. doi:10.2307/2224098, 1928

[7] G. Casella, R.L. Berger, Statistical Inference. 2nd. Pacific Grove: Thomson Learning, 2002

[8] S.A. Ross, R.W. Westerfield, J.F. Jaffe, Corporate Finance. 10th . New York: McGraw-Hill/Irwin., 2013

[9] Badan Pusat Statisik, Indeks Harga Konsumen dan Inflasi Bulanan Indonesia. Accessed December 13, 2019.

[10] U.S. Burearu of Labor Statistics, Consumer Price Index Archived News Releases. December 13, 2019

[11] L. Cuesta, E. Vallarino, Hydropower Projects." Chap. 2, 86-89. Madrid: Ed. Ibergarceta, 2015

[12] PLN, Energy Optimism for Indonesia. Annual Report, Jakarta: PT Perusahaan Listrik Negara (Persero), 2019

[13] J. Piel, J.F.H. Hamann, A. Koukal, M.H. Breitner, Promoting the System Integration of Renewable Energies: Toward a Decision Support System for Incentivizing Spatially Diversified Deployment." Journal of Management Information Systems (Routledge) 994-1022, 2017