The economics comparison of power plants fuelled by wellhead gas and liquefied natural gas in Aceh Province

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Abstract. The Aceh Province Electricity System is supplied by Gas Engine Power Plant (GEPP) fuelled by Liquefied Natural Gas (LNG), Coal-fired power plant and Diesel Engine with Diesel fuel and transfers from the North Sumatra system during peak loads. LNG fuel is sent by ship from the Tangguh Papua Refinery which is regasification in Perta Arun Gas, Lhokseumawe, Aceh Province, so the production costs are expensive due to the distance from the gas supply sources. To get cheaper electricity production costs, it can be done by using the gas potential in Aceh province. In this study, the economic value will be calculated by comparing the use of two types of gas fuel, namely wellhead gas fuel and LNG gas for Gas Turbine and Gas Engine power plants, to determine the cost of electricity production for each power plant with the same fuel. Based on the calculation results, gas engine power plant with fuel from the Wellhead Gas has the best production costs with value of IDR 1,262.21 / kWh lower than the electricity tariff of IDR 1,467 /kWh, and has an IRR of 24.78% and a payback period of 4.88 years. By knowing the most economic value for the construction of power plant with Wellhead Gas, it can be used as a basis for policy making in choosing an economical power plant development for areas with gas potential, such as in Aceh province.

1. Introduction
Energy is a primary need in modern human life, almost all aspects of life require energy as the prime mover. Global energy consumption is predicted to increase by approximately a third by 2040, with fossil fuels being the predominant energy sources [1]. The vast territory of Indonesia contains energy potential for fossil and renewable energy that has the opportunity to be used as a source of electrical energy. Natural gas is a Non renewable energy source, it is identified as low carbon emitter for power generation and transport globally [2]. Aceh Province is a province located north of the island of Sumatra, which has potential primary energy sources consisting of potential coal, water, geothermal, petroleum and gas which can be used for electricity generation. Natural gas from Aceh and Northern Sumatra has long been produced. The Arun field in Aceh has been producing since the 1970s to meet the needs of fertilizer factories, power plants and LNG exports[3]. Based on data from the National Energy General Plan for 2017, total natural gas reserves in Aceh amounted to 7,516.3 BCF in the form of proven reserves of 1,420.8 BCF, probable reserves of 4,720.4 BCF and possible reserves of 1,375 BCF. Apart from natural gas supplies from fields in Aceh and Northern Sumatra, currently natural gas is also imported from Tangguh Papua through to the Arun Regasification Terminal.

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The electric power system in Aceh consists of a 150kV North Sumatra-Aceh interconnection system and an isolated system with a distribution voltage of 20 kV. Most of Aceh's electricity power system is supplied by the 150 kV North Sumatera interconnection system and a small part is still in isolated areas. The Aceh Province Electricity System is supplied by the Coal Power Plant located in Meulaboh, the Gas Engine Power Plant (GEPP) fuelled by Liquefied Natural Gas (LNG) located in Lhokseumawe and the Diesel Engine Power Plant is spread using diesel fuel as well as transfers from the North Sumatra system during load peak. The highest peak load of the Aceh system in 2018 was 424 MW in July[4]. The average growth of electrical energy in Aceh province for 10 years is 8.11% with the consideration of economic growth and in Aceh province, the Arun Lhokseumawe Special Economic Zone will be built, several cement factories and industrial areas [4].

Liquefied Natural Gas (LNG) fuel for Gas Engine Power Plant is shipment from the Tangguh Papua Refinery which is regasification at Perta Arun Gas, Lhokseumawe, Aceh Province and then flowed through gas pipes to the power plant location, so the production costs are expensive because of the distance the source of gas supply as well as the regasification process. To get cheaper electricity production costs, it can be done by using the gas potential in Aceh province so that electricity production costs can be more economical. Aceh Province is an area that has gas potential, currently this potential has not been optimally utilized for the electricity sector. Electricity generation cost assessment are typically use to rank different power generation technologies based on to expected generation cost and to estimate economic subsidies or penalty charges needed. As such, generation cost assessments are important in energy decision and policy making [5].

In this study The economic calculation of gas-fired power plants is used to determine the economic value of the production costs of electricity generated by the power plant for the use of LNG gas fuel and the well head gas fuel located in the province of Aceh, Economic analysis such as Net Present Value (NPV), Internal Rate of Return (IRR) and Payback Period are calculated for considering economic feasibility. Knowing the economic production costs will be the basis consideration of the policy for selecting the type of fuel and type of power plant to be built in Aceh province.

2. Materials and methods
Natural Gas is one of the world’s abundant sources of energy. Natural gas is the fastest growing fossil fuel with its global consumption expected to increase by 1.9%/year. Natural Gas is usually transported in either pipeline as gas or special marine tanker as cryogenic liquid after exploration and treatment [6]. Natural gas can be distributed in two forms, namely the liquid phase and the gas phase. In the gas phase, natural gas from gas wells can be distributed in piped gas or Compressed Natural Gas (CNG). Well Head gas is natural gas fuel located near the upstream oil and gas production facilities or gas that is flowed through pipes that have never undergone a regasification process[4].

In the liquid phase, natural gas is distributed in the form of Liquefied Natural Gas (LNG). LNG is natural gas that converted to a liquid state by cooling it down to approximately -162 °C. In this liquid state, it takes up much less volume compared to a (compressed) gaseous state, which make LNG particularly suitable as a fuel for long-haul transportation[7]. It is more efficient for transportation. The LNG supply chain can be described as a network of natural gas from the gas field/gas well to the liquefaction plant to turn the gas phase into liquid[8]. The purpose of changing the gas phase to the liquid phase is to facilitate the transportation and storage processes. For the shipping process, usually using the shipping process before being used for power plant needs, LNG will go through a regasification process, where the LNG phase changes from the liquid phase to the gas phase again and after that it will be channel through the pipeline. Natural gas market consists of producers, pipeline operators and local distribution companies on the supply-side and electrical, industrial, commercial and residential customers on demand-side Natural gas is first purchased at the wellhead by independent brokers and pipeline companies for direct delivery to electrical and industrial customers[9].

To meet the increasing demand for electricity supply, PLN needs gas on a very large scale for electricity generation[10]. Gas Fired Unit has become the most potential fossil generation, for its
cleanliness and high efficiency [11]. Utilization of the potential for natural gas for power generation will encourage increased achievement of natural gas potential utilization. Unlike other usual gas well, natural gas supply of LNG terminal is influenced by the risk of LNG supply, which caused by shipping or bad weather on sea [11]. Gas fuel supply constraints will have an impact on the operational side of the plant, with the construction of a generator in accordance with the gas potential that is owned, it will reduce the potential for this problem. Aceh Province with the availability of gas energy potential that is owned and has not been maximized for power generation can be a priority for planning the development of power plants by considering its economy compared to natural gas which is currently used for power generation in Aceh province.

Comparison of the economics of the use of LNG gas fuel and Well Head gas fuel used for gas-fired power plants. In order to produce affordable electric power, in choosing the energy resources to be used to carry the electrical load, an economic analysis of the cost of generation is necessary.

Comparison of economic calculations by comparing the use of two types of fuel gas, namely well head gas and LNG gas for Gas Turbine Power Plant (GTPP) and Gas Engine Power Plant (GEPP), to determine the electricity production costs of each power plant with burn the same.

3. Results and discussion

Economic analysis is undertaken for making sure the feasibility investment of design from economic review. Electricity production cost prices are calculated by applying electricity calculations where transmission costs are not included in the calculation. The price of electricity is the average cost which is the cost required per kWh which takes into account all cost components including capital costs, operating costs and fuel costs[12]. The calculation of the cost of generation by taking into account the electricity generation Et (kWh) in year t, the average cost in year t, denoted B in mills / kWh or IDR /kWh is

\[ B = \frac{1000 \times Ct}{Et} \quad (1) \]

Where Ct ($) is the costs incurred for operating costs, fuel and capital return costs for year t. With the price of electricity for each year, during the life of the generator (N years), the present value of revenue from electricity sales Rv’ is

\[ Rv' = \sum_{t=1}^{N} \frac{B \times Et}{1000(1+di)^t} \quad (2) \]

Where di is the amount of the discount rate. Rv’ will be equal to the present value of costs incurred for the Ct’ operation.

The formula for the levelized cost or tariff price B’-(mills / kWh or IDR /kWh) is

\[ B' = \frac{\sum_{t=1}^{N} \frac{Ct}{(1+di)^t}}{\sum_{t=1}^{N} \frac{Et}{(1+di)^t}} \quad (3) \]

Levelized cost of electricity generation is essentially the total cost of producing power over the lifetime of the unit divided by the total electricity generated in the same time period[13]. The levelized tariff or cost can be calculated by the equation.

\[ \text{Levelized tariff} = \frac{\text{Total Cost in net present value}}{\text{Total Energy in NPV salable energy}} \quad (4) \]
Economic analysis is carried out to determine the economic value of an investment, for investment in power plants. Some of the values analysed are Net Present Value (NPV), Internal Rate of Return (IRR) and Payback Period.

Net Present Value (NPV) is a method for calculating the net present value of investment cash flows by applying the money equivalent concept. Investments will be considered feasible if the NPV value is greater than zero and investment is considered unfeasible if the NPV is less than zero[14]. The formula for determining the NPV value is like formula 5 below. The NPV value is equal to the present value of cash inflows minus the present value of cash outflows or the Present Value (PV) of all expected cash flows[15].

\[
NPV = \sum_{t=1}^{N} \frac{CF_t}{(1+r)^t}
\]  

(5)

Where \( CF_t \) is cash flow \( t \) is time period, \( N \) is number of time periods and \( r \) is interest (interest rate).

Internal Rate of Return (IRR) is a method used to evaluate the feasibility of investing in terms of the level of cash flow ability to return investment, which is described in terms of a percentage per time period [14]. The formula for obtaining the IRR value is as in formula 6 below.

\[
IRR = i_{NPV}^+ + \frac{NPV^+}{NPV^+ + NPV^-} (i_{NPV}^- + i_{NPV}^+ )
\]  

(6)

Where IRR is the Internal Rate of Return in percent (%), \( i_{NPV}^+ \) and \( i_{NPV}^- \) are the interest rates for positive and negative NPV.

Payback period is an investment feasibility analysis method to determine the investment return period when the return on investment occurs [15]. The payback period value can be obtained by using an equation such as formula 7 below.

\[
Payback\ Period = n + \frac{a-b}{c-b} \times 1\ year
\]  

(7)

Where \( n \) is the last year where the total cash flow has not covered the original investment, \( a \) is the initial investment amount, \( b \) is the total cash flow investment in year \( n \) and \( c \) is the total cash flow investment in year \( n+1 \).

The Power plant used for the calculation of investment costs are gas-based power plants with the type of Gas Turbine and Gas Engine Power Plants with a total load approximately 100 MW and capacity factor 81%. The gas turbine used is Gas Turbine Type SGT A-65 DLE with a load of 55 MW per unit, while the gas engine used is the type 18V51 / 60 with a load of 17 MW per unit. The total investment cost is the total cost of Engineering, Procurement and Construction (EPC) and Non EPC costs. EPC costs consist of civil work costs, mechanical work, electrical and instrument work and other costs while Non EPC costs consist of owner costs, value added taxes, interest during construction and contingency fees. In the Table 1, investment cost of Gas Turbine and Gas Engine Power Plant is presented.

| No | Description             | Gas Turbine (IDR) | Gas Engine (IDR) |
|----|-------------------------|-------------------|------------------|
| A  | EPC Costs               |                   |                  |
| 1  | Civil Works             | 146,859,330,695   | 223,234,538,181  |
| 2  | Mechanical Work         | 1,103,449,225,571 | 849,656,650,821  |
| 3  | Electrical and Instrument Work | 273,807,103,444 | 190,533,729,876 |

Table 1. Investment Cost.
Based on the table above, the largest cost is for mechanical work, which is the purchase of a power plant machine with a percentage of 67% of the EPC cost for gas engines power plant and 72% of the EPC costs for gas turbines power plant. The total cost for the construction of a Gas Turbine Power plant is IDR 1,997,578,269,445. Meanwhile, the total cost for the construction of a Gas Engine Power plant is IDR 1,683,385,346,275.

Operation and Maintenance (O&M) costs are divided into two, namely fixed costs (Component B) and variable costs (Component D), where O&M fixed costs for Gas Engine power plant are IDR 90.77 / kWh and O&M variable costs are 45.53 IDR / kWh. As for the Gas Turbine power plant, the O&M fixed cost is IDR 27.20 / kWh and the O&M variable cost is IDR 84.69 / kWh. Use of the operating and maintenance cost assumptions based on the operation and maintenance costs that have been implemented in the PLN project.

The price of Liquefied Natural Gas fuel used in this study is Liquefied Natural Gas in Arun, Lhokseumawe which is shipment from the Tangguh Papua Gas Refinery which is sent via LNG ship and regasification at the Arun regasification plant. The gas price at the plant gate based on Decree of the Minister of Energy and Mineral Resources No.91K / 12 / MEM / 2020 concerning the price of natural gas at the Power Plant for Northern Sumatra is $ 7.5 / MMBTU.

The price of gas fuel comes from gas well head in the Aceh region, with the assumption that the gas price for power plant with the well head gas according to Decree of the Minister of Energy and Mineral Resources ESDM No.10 of 2020 is a maximum of $ 6 / MMBTU.

To make an economic comparison of the use of gas fuel between Liquefied Natural Gas and well head gas for gas engine and gas turbine power plants, an economic calculation is carried out for power plants fuelled by Liquefied Natural Gas and wellhead gas. Calculating the NPV, IRR and payback period for investment in gas turbine power plants and gas engine power plants with Liquefied Natural Gas fuel with a design life of a power plant of 25 years and a discount rate of 9.8%, the comparison of the economic value for a power plant fuelled by Liquefied Natural Gas is obtained as in Table 2.

| No  | Description                     | Value                  |
|-----|---------------------------------|------------------------|
| 1   | Design Life                     | Gas Turbine            |
| 2   | Discount Rate                   | Gas Engine             |
| 3   | NPV Total Cost                  | IDR. 9,545,944,449,000| IDR. 8,544,473,071,000|
| 4   | NPV Saleable energy             | 6,479,307,304 kWh      | 6,178,872,117 kWh     |
| 5   | Production cost                 | IDR 1.473,30 /kWh      | IDR 1,382,85 /kWh    |
| 6   | IRR                             | 16.53%                 |
| 7   | Payback Period                  | 7,23 Years             |

NPV, IRR and payback period calculations are also carried out for investment in gas turbine power plants and gas engine power plants using wellhead gas with a design life of a power plant of 25 years...
and a discount rate of 9.8%, a comparison of the economic value for wellhead gas-fired power plants is obtained the results are as in table 3.

Table 3. Results of the Calculation of a Well Hell Gas fired Power Plant.

| No  | Description               | Gas Turbine Value | Gas Engine Value |
|-----|----------------------------|-------------------|------------------|
| 1   | Design Life               | 25 Years          | 25 Years         |
| 2   | Discount Rate             | 9.8%              | 9.8%             |
| 3   | NPV Total Cost            | IDR. 8.650.463.154.000 | IDR. 7.799.055.516.000 |
| 4   | NPV Saleable energy       | 6.479.307.304 kWh | 6.178.872.117 kWh |
| 5   | Production cost           | IDR 1.335.09 /kWh | IDR 1.262.21 /kWh |
| 6   | IRR                        | 20.94%            | 24.78%           |
| 7   | Payback Period            | 5.75 Years        | 4.88 Years       |

From the above results, it is obtained a positive NPV value, which means that the construction of gas-fired power plants is feasible and has an IRR value that is greater than the interest rate for all types of power plants with each fuel used so that economically the development of a gas fire power plant with well head gas and LNG fulfill the element of feasibility.

Based on the calculation results, the production cost of the construction of a Gas Turbine power plant using LNG gas is IDR 1,473.30 / kWh while for a Gas Engine power plant using LNG gas fuel is IDR 1,382.85 / kWh. If the power plant uses gas from the well head gas, then the production cost for a Gas Turbine power plant is IDR 1,335.09 / kWh while for Gas Engine power plant is IDR 1,262.21 / kWh. Where the production costs are below the cost of providing the power generation PT. PLN for the Aceh region, namely IDR 1,673 / kWh and could potentially reduce the cost of providing generators in Aceh province.

When compared with the PLN electricity selling rate of IDR 1,467.28 / kWh, only gas turbine power plants with LNG fuel have a value greater than the selling rate, while Gas engine power plants using LNG and well head gas fuels and gas turbine power plant using well head gas have lower production costs than the selling rate of electricity. This will provide benefits due to lower production costs compared to PLN's electricity sales tariff.

Utilizing natural gas for electricity generation in Aceh province will make a positive contribution to the electricity system economically.

4. Conclusion

Based on the above economic analysis, gas engine power plant with gas from the well head gas has an electricity tariff of IDR 1,262.21 / KWh cheaper than the selling value of PLN electricity of IDR 1,467.28 / KWh, for a gas engine power plant with gas fuel from the well head gas has a better economic value with an IRR of 24.78% and payback period of 4.88 years so that the gas engine power plant with gas from the Well Head gas can be a consideration for the policy of selecting the construction of gas fired power plants in Aceh province.

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