Technical and economic analysis use of flare gas into alternative energy as a breakthrough in achieving zero routine flaring

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Abstract. The activity of exploring natural oil and gas will produce gas flare 0.584 MMSCFD. A gas flare is the combustion of gas remaining to avoid poisonous gas like H₂S and CO which is very dangerous for human and environmental health. The combustion can bring about environmental pollution and losses because it still contains valuable energy. It needs the policy to encourage the use of flare gas with Zero Routine Flaring and green productivity to reduce waste and pollution. The objective of the research was to determine the use of gas flare so that it will have economic value and can achieve Zero Routine Flaring. It was started by analysing based on volume or rate and composition gas flare was used to determine technical feasibility, and the estimation of the gas reserves as the determination of the economy of a gas well. The results showed that the use of flare gas as fuel for power generation feasible to be implemented technically and economically with Internal Rate of Return (IRR) 19.32% and the Payback Period (PP) 5 year. Thus, it can increase gas flare value economically and can achieve a breakthrough in Zero Routine Flaring.

1. Introduction
Oil production is accompanied by associated natural gas as the valuable by-product of oil processing [1]. A Gas flare is a by-product of exploration and exploitation of oil wells, refinery process, the petrochemical process in the form of associated gas. Natural gas which simultaneously comes out with oil petroleum poses risks during exploration and processing so that in handling this gas is often burned on the flare stack to keep the production equipment from overpressure. Burning is a high-temperature oxidation process used to burn combustible components, mostly hydrocarbons, waste gas from industrial operations. During the combustion process, the hydrocarbon gas reacts with oxygen to form carbon dioxide (CO₂) and water. In addition to CO₂ being exhausted into the air, there is carbon monoxide (CO) as the main component of flammability. Some intermediate products are formed during combustion reactions that most of them converted to CO₂ and water. Some amounts of stable intermediate products such as carbon monoxide, hydrogen, and hydrocarbons will escape into the air as emissions [2].

The flare gas is substantially dominated by methane and carbon dioxide. The combustion process of these gases is a major contributor to the supply of greenhouse gases in the atmosphere and adds to
the chaos of climate change [3]. In addition to the impacts on the environmental, burning of residual gas may pose a health risk. Gas flare contains toxins that pollute the air. There are more than 250 toxins that had been identified and released from combustion including carcinogens such as benzopyrene, benzene, carbon disulfide (CS$_2$), carbonyl sulfide (COS) and metallic toluene such as mercury, arsenic, and chromium; Acid gas with H$_2$S and SO$_2$ as well as nitrogen oxide [2]. Benzene, naphthalene, styrene, acetylene, fluoranthene, anthracene, pyrene, xylene, and ethylene are the most commonly found in one of the combustion emissions [3]. Other effects of CO$_2$ contamination on the environment can be known, as in plants, the occurrence of white or red brown spots on the surface of plant leaves, consequently the production of agricultural products has decreased in the long run impacts on economic growth. In other words, gas combustion has violated the principles of sustainable development and seriously contributes to global warming [5].

Some policies issued on a global and national scale to limit combustion activities on an ongoing basis to maintain environmental sustainability such as:

- Zero Routine Flaring by the World Bank as an initiative to reduce gas flare that contributes significantly to climate change. This policy aims to unite the government, oil companies and other development agencies to cooperate in a sustainable way to eliminate combustion activity. Including Indonesia, based on the data of World Bank data is the order of the ten largest gas flare producing countries in the world with 3.5 billion cubic metres (bcm) of flaring. Of the burning, Indonesia added about 12 million tons of CO$_2$ into the atmosphere and wasted more than the US $ 400 million every year [7];
- The Environment Minister Decree No.129 of 2003, which regulates the quality standard of business emission in oil and gas activities. This focuses on monitoring gas emissions and prohibits burning of gas waste openly;
- The Government Regulation No.34 of 2005 which regulates the activities of upstream oil and gas business. The Government Regulation contains the obligations of the upstream oil and gas business entities to manage the environment including the management of gas flare. The above policy has the same goal to reduce gas combustion by utilizing the gas, because it still has energy as well as natural gas. Several studies were conducted regarding the utilization of this gas include: Obayopo utilizes gas flares to Gas to Liquid (GTL) as a substitute for diesel fuel [1]. Idowu undertook research to reduce gas combustion by setting up a liquefied natural gas plant to be channeled to several neighboring countries in Nigeria [7]. Widyantoro analyzes the utilization of gas flares as a substitute for High-Speed Diesel (HSD) fuel for power generation [8]. Sugiarto utilized gas flares as for domestic gas networks [9].

Research for the use of flare gas is more interesting to be studied in connection gas combustion in addition to impact on environmental damage is also a loss for wasting energy that is still valuable. Gas flares can be used as alternative energy from petroleum and natural gas. However, this requires further study because each location or gas field has different characteristics in terms of production volume, the amount of reserves and composition of hydrocarbons.

Handiko mentions that the utilization of gas flare was influenced by the volume and rate of gas, composition, reserve age, position and capacity of consumers to be addressed [10]. In this study, the determination of alternatives gas flare utilization begins with an analysis of volume or rate and composition gas flare. Then determined the remaining reserves gas using decline curve analysis method as a economic consideration the gas well.

The technical and economic analysis are used in the selection of potential alternatives that will be implemented by the company. Technical analysis is related to the feasibility of the process, operating conditions, and the resulting product. Economic analysis is done to assess the feasibility of investment by using parameters Internal Rate of Return (IRR) and Payback Period (PP). If the analyzed alternatives are technically and economically feasible to do, then the alternatives can be implemented by the company to achieve Zero Routine Flaring and environmentally friendly.
2. Method
The method used in the study using a technical and economic approach. The purpose of technical analysis is to determine which alternative can be applied technically by taking into account the technology to be used and the physical needs of the project.

The steps which is used in this research are:

- **Formulate problems and research objectives:**
- **Data collection.** The data which is used for the analysis of gas utilization include are: production data, gas composition data, economic limit rate, gas engine specification and capacity, LPG product price and electricity, natural gas price, interest rate, tax, and equipment and machine price data required. All of them can be obtained from company reports, statistics, journals and literature related and support the argument of this research;
- **Data processing.** Based on data that has been collected then performed data processing to determine the alternative gas utilization based on the volume or rate and composition of gas flare. Then calculate the estimated reserves reservoir as a consideration in determining the economy;
- **Technical and economic analysis.** Technical analysis is related to the technology that will be applied into the system. If based on the technical analysis is feasible then the economic analysis is done. Conversely, if not obtained the requirements then the alternative is considered not technically feasible and the another alternative test is done. Economic analysis is done by using Internal Rate of Return (IRR) and Payback Period (PP). Investment is categorized as economically viable if the IRR> MARR and Payback Period are less than the gas reserves. If the parameters are not fulfilled then the alternative is not economically feasible.

3. Results and Discussions

3.1. Determination utilization of the gas flare
The determination of alternatives gas flare utilization are analyzed based on volume or rate and composition of the gas flare.

3.1.1 Based on volume or rate of gas flare. The formula that is used to calculate volume of gas flare as follow by [11]:

\[
\text{Gas flare} = \text{gas produced} - \text{gas utilized}
\]  

Based on the production data processing, the volume of gas flare on average is 0.584 Million Standard Cubic Feet Per Day (MMSCFD) equivalent to 16.527 m³ of gas burned per day. Based on the volume, utilization alternative of gas flare that allows to the company is to make gas flares as fuel power plant, raw materials Small Scale Liquid Natural Gas (LNG) and Mini plant Liquefied Petroleum Gas (LPG). Small Scale LNG can be applied for refinery capacity below 2.5 MMSCFD or 600-700 kilo tons/year. The development of this LNG mini is very suitable to small gas field, and its location is spreading [10].

3.1.2. Based on composition of gas flare. Composition of gas was obtained based on the result of the laboratory test using the gas chromatography method. Gas chromatography is similar to fractional distillation to separate the components of the mixture based on the difference in the boiling point. The result of the test can be seen in Table 1 below.
Table 1. Composition of gas flare.

| Component               | Value | Unit  |
|-------------------------|-------|-------|
| Nitrogen (N₂)           | 0.32  | %mol  |
| Carbon dioxide (CO₂)    | 1.99  | %mol  |
| Methane (CH₄)           | 58.78 | %mol  |
| Ethane (C₂H₆)           | 12.92 | %mol  |
| Propane (C₃H₈)          | 8.94  | %mol  |
| i-Butane (C₄H₁₀)        | 3.68  | %mol  |
| n-Butane (C₄H₁₀)        | 4.17  | %mol  |
| i- Pentane (C₅H₁₂)      | 2.91  | %mol  |
| n- Pentane (C₅H₁₂)      | 1.67  | %mol  |
| Hexane Plus (C₆⁺)       | 4.61  | %mol  |
| Specific gravity (beral jenis) | 1.05 | Btu/Scf |
| Gross Heating Value (GHV) | 1719.68 | Btu |

Based on Table 1 the methane component is 58.78 %mol (below 80 %mol) while the weight fraction (propane and butane) was 12.62 mol%. The weight fraction including high and can cause incomplete combustion (resulting in black smoke C) in the fuel so that it must be separated by utilizing the gas as the raw material for producing LPG. Gross Heating Value (GHV) based on table is 1719.68 BTU or equivalent to 1162.43 BTU/SCF. This value is within the limits of the specifications required for the power plant power plant (950-1250 BTU/SCF). So the possible alternative utilization of gas flare is to make it as raw material for LPG and fuel power plant.

The result of analysis regarding volume or rate and composition gas flare is then selected the dominant alternative as follow on Table 2.

Table 2. Gas Flare Utilization Based on Volume or Rate and Composition

| Factor                  | Criteria                      | Alternative | Power Plant | Mini Plant LPG | Small Scall LNG |
|-------------------------|-------------------------------|-------------|-------------|----------------|-----------------|
| Volume or Flow rate Gas flare | Volume/flow < 2.5 MMSCFD     | √            | ✗            | ✗              | ✗               |
| Compostion gas flare    | Methane < 80%mol              | √            | ✗            | ✗              |                 |
|                         | Propane & butane > 10%mol     |              |             |                |                 |
|                         | GHV 950-1250 Btu/scf          | √            |             |                |                 |
| Number of fulfill criteria | 3                            | 3            | 1            |

Based on Table 2, the chosen alternative dominantly fulfill the factor of volume or rate and composition of gas flare i.e., making gas flares as fuel for power generation and raw material of mini plant LPG.

3.2. Determination the remaining reserves of gas

Determination the remaining reserves of gas aims to obtain an overview of the prospects for future gas production, so as to determine the best course to develop the field [12]. One of the methods used to determine the remaining reserves of gas is the decline curve analysis. Decline curve analysis can
estimate oil or gas based on production data after a time interval. The result of analysis by decline curve analysis is obtained that gas field reserves are still economically produced during the eight years.

3.3. Alternative of gas flare utilization as raw material of mini LPG plant

Liquefied Petroleum Gas (LPG) is one of the most widely and alternative fuels used in today's world [4]. LPG consists of a mixture of propane (C₃H₈) and butane (C₄H₁₀) and some lighter C₂ fractions and a heavier C₅. The acquisition of LPG from gas field depends on the composition of the gas produced from the well. Natural gas containing many hydrocarbon components (C₃ and C₄) which can be utilized as raw material LPG production.

3.3.1. Technical feasibility analysis of mini LPG plant. Technical feasibility analysis is related to the appropriateness of the process, operating conditions, and the resulting product. The process of separating the C₃ and C₄ components from natural gas is carried out against the reduced moisture content and the acidic gases (H₂S and CO₂). To separate the heavy fraction can be done by the following process stages on Figure 1:

![Figure 1. Production process stages of LPG.](image)

Mini LPG Plant in addition to producing LPG also produces a by-product of fuel that still has economic value in the form of condensate and lean gas that are used as fuel for power plants. Schematically the product of mini LPG can be seen in the following Figure 2:

![Figure 2. Product of mini LPG plant.](image)

Some of the major equipment used for processing gases into LPG is as follows:
- Compressor;
- Gas Separator;
- Absorber and Stripper;
- Fractionator;
- CO2 removal.

If the gas flares generated by 0.584 MMSCFD is used for mini LPG then it can produce as follow:
LPG 3.69 tons per day, Condensate 8.25 barrel per day and Lean gas 0.49 MMSCFD. Technically the utilization of gas flares into LPG products is feasible because the process and the technology can be implemented and products easy to be marketed.

3.3.2. Economic analysis of mini LPG plant. Economic analysis is conducted to examine the balance of costs incurred with projected profits which will be obtained. The assumptions used in the economic analysis are as follows:
- Currency exchange rate adjusted to the exchange rate during the analysis.
- Projection period
- Financial analysis is carried out with projections over the seven years after commercially operating from the 1st to 8th year. Thus at the beginning of the first year the company has commissioned.
- The interest rate is adjusted with the bank interest rate during the period of analysis
- Income tax refers to Law No.36 of 2008 with income tax rate is 25% which is valid since 2010.
- Working days per year is 300 days and 24 hours per day.
- Production cost consisting of:
  - Labor costs. Direct labor is the required worker in production activities whose existence depends on the volume and day of operation;
  - Operational cost used for utilities is 2% of total revenue;
  - Maintenance costs of 2% a total investment in machinery and equipment;
  - The cost of raw materials is gas flare with assumed the purchase price is USD 1412 per MMSCFD or Rp.18.701.940/MMCFD;
  - Insurance fee of 0.2% of the cost of building, machinery, and equipment;
  - The selling price of the mini LPG plant product are: LPG Rp. 11.814.000/ton, Condensate Rp. 1,008,620.25 /barrel and Lean Gas Rp. 29535 /MMBTU;
  - The funding source for mini LPG plant development comes from the private sector (developer) who cooperates with Build Operate and Transfer (BOT) with the company. In this case, the company acts as the owner providing the project location. Capital investments in the form of equipment and machinery used in mini LPG plant provided by the developer. The cost required for the construction of mini LPG comes from the investment of the developer by estimating the cost of Rp. 197.709.975.000 investment and Rp.8.896.948.875 self-financing.

Based on the results of economic analysis it is found that mini plant LPG project is not economically feasible because the investment is much greater than the profit obtained with the return rate of IRR <MARR and PP> economic limit rate of available gas reserves. So that alternative use of gas flare as the raw material of mini plant LPG can not be implemented economically.

3.4. Alternative utilization of gas flare as fue of power plant
The process of generating electricity by using gas fuel as turbine or engine drive. The principle of action is to change the heat energy generated from the combustion chamber is converted into mechanical energy and then converted into electrical energy.

3.4.1. Technical feasibility analysis of power plant. The process of generating electricity using gas fuel requires several major components consist are: air filter, compressor, combustion chamber, turbine, exhaust stack and generator [13]. Commonly used generator types are gas turbines and gas engines.
Gas turbines have relatively lower installation costs with relatively low emissions, but generated efficiency is relatively low. Gas Engine is technically feasible compared to Diesel Engine and dual fuel steam turbine although its investment cost is more expensive than other power plant types.

To determine the electric power generated from the plant using a gas fuel is determined based on the gross heating value (GHV) and gas volume. The determination of electric generated can be calculated using energy conversion tables. Based on the calculation, 0.584 MMSCFD flares gas can be generated approximately 1.3 MegaWatt (MW). Next looking for Gas Engine Generator brands that have capacity approximate the above needs. From several Genset makers obtained capacity per unit of Genset and number close to requirement as shown in Table 3.

Table 3. Power comparison of some gas engine brands.

| Brand of Gas Engine | Power Installed (kW) | Efficiency | Power Generated (kW) |
|---------------------|----------------------|------------|----------------------|
| Deutz               | 2934                 | 80%        | 2347                 |
| GE Jenbacher        | 2423                 | 80%        | 1946                 |
| Cummins             | 2000                 | 80%        | 1600                 |
| MWM                 | 800                  | 80%        | 640                  |
| Siemens             | 225                  | 80%        | 180                  |

Based on Table 3 to generate 1.3 MW energy required Gas Engine Generator MWM brand of 2 units with a capacity of each 800 Kilo Watt (KW). The consideration of using two units engine is for efficiency reasons if one of these breakdowns occurs the production of electricity does not stop. The use both of gas engine can produce a total of 1280 kW of power generated with 80% efficiency.

3.4.2. Economic feasibility of power plant. Economic analysis is carried out using the following assumptions:

- Currency exchange rate adjusted to the exchange rate during the analysis;
- Projection period. Financial analysis is carried out with projections over the seven years after commercially operating from the 1st to 8th year. Thus at the beginning of the first year the company has commissioned;
- The interest rate is adjusted with the bank interest rate during the period of analysis
- Income Tax refers to Law No.36 of 2008 with income tax rate is 25% which is valid since 2010;
- Working days per year is 300 days and 24 hours per day;
- Production cost consisting of:
  - Labor costs. Direct labor is the required worker in production activities whose existence depends on the volume and day of operation.
  - Operational cost used for utilities is 2% of total revenue
  - Maintenance costs depend on operating hours and frequency of use of the plant, amounting to 2% of the total investment in machinery and equipment.
  - The cost of raw materials for power plants is gas flare which is the residual gas from the production activity. The price of gas flare customized to the Ministerial Decree of Energy and Mineral Resources No. 3 of 2015 on the procedure of purchasing electricity and the purchase price of electricity with gas price is US $ 6/MMBTU or Rp.79.470/MMBTU.
  - Insurance costs are assumed to be 0.2% of the cost of buildings, machinery, and equipment.
The selling price of power refers entirely to the fixed price of electricity in 2016 of Rp.1509 per kWh. Based on the price index for Sumatra area 1.15 then, the selling price of electricity Rp. 1735 per kWh.

The fund source for the development of this power plant comes from the private sector (developer) who cooperates with the BOT of the company.

The recapitulation economic feasibility analysis of the power plant project is presented by the Table 4.

| No | Description                           | Amount          |
|----|--------------------------------------|-----------------|
| A  | Cash Proceed                         |                 |
|    | 1. Net Income                        | 39,746,791,400  |
|    | 2. Depreciation/Amortization         |                 |
|    | **Total cash proceed**               | 52,181,855,825  |
| B  | Cash Outlay                          |                 |
|    | 1. Increase/decl in NWC              |                 |
|    | **Total Cash Outlay**                | 28,774,314,878  |
| C  | Net Cash Proceed                     | 23,407,540,947  |
| D  | Kum.Net Cash Proceed                 |                 |
| E  | Discount Rate                        | 13.06%          |
|    | PV of Benefit                        | 6,814,950,371   |
|    | PV of Cash Outlay (amortiz)          | 3,757,925,523   |
|    | Net Present Value (NPV)              | 3,057,024,848   |
| F  | Internal Rate of Return (IRR)        | 19.32%          |
| G  | Pay Back Period                      | 5 Tahun 0 Bulan |

Based on Table 4, the IRR value of the project is 19.32% and PP for five years. The value of IRR is greater than the interest of the bank at 11% with a significant difference. Based on the value of Net Present Value (NPV), the development of gas industry follow-up in the research location is good enough, and the company will profit Rp. 3,057,024,848 for eight years. The calculation of payback investment company is 5 years, it means that the time which required to return capital faster than remaining reserves of gas will be run out or before the contract expires, so that in the fifth year the company earns a profit equal from the difference between proceeds of sale with cost or capital expended. The result of this economic feasibility analysis shows that the power plant project using gas flare is feasible to be implemented by the company.

If this alternative proposal is implemented, it will have a positive impact on the economic growth of the company and the surrounding community. Besides, this will have a positif effect on the sustainability of the environment by reducing the potential for pollution and harmful gas emissions. Globally the utilization of gas flare reduces the greenhouse gas effect. Thus there is no more gas flare so that the zero routine flaring condition will come true.

**Sensitivity Analysis**

The measured changes are:

- The availability of raw materials (gas flares) decreased by 5%
- Production cost up 10%
As a parameter to assess the sensitivity of the above conditions change is the value of the project IRR. Based on calculated, the project IRR is 19.32%. While in the above-mentioned change conditions, the project IRR changes as follows:

- Supply of raw materials (flare gas) decreased 5%, IRR value changed to 18.89%
- Production costs rose 10%, IRR value become 18.75%

Therefore, the project is more sensitive to changes in gas flare fluctuations and increases in production costs.

4. Conclusions
Based on the results of the discussion in this study it can be concluded as follows:

- Based on the analysis of the volume or flow rate and composition of gas flare, the alternative usage is to make alternative energy for power plants and raw materials to produce LPG;
- Technical analysis shows that the utilization of gas flare as raw material for the power and mini LPG can be implemented by the company;
- The calculation of economic feasibility indicates that the alternative utilization of gas flare as raw material for the power plant is feasible to be implemented by the company with IRR 19.32% and PP for five years;
- The use of gas flare as an alternative energy for fuel power plant can increase the value of gas flare economically, as well as an achievement of Zero Routine Flaring, and environmentally friendly.

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