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Implementation of Latest Technology in Oil and Gas Industry Business Processes: Case Study of Production Processes in Upstream Oil and Gas with Zero Flaring Technology

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ABSTRACT

This study aims to evaluate and implement the latest technology in reducing flare gas (Flare Gas Recovery) in the upstream oil and gas industry. Flare gases, which are often burned and released into the atmosphere, are a significant source of emissions and a contributor to warming. The results of the SWOT and AHP analysis show that the technology of converting flare gas into electrical energy has advantages compared to other technologies. From an economic perspective, calculations show that this project is very feasible to implement, with an NPV value of IDR 48.82 billion, an IRR of 23.03%, a BCR of 1.14, and a payback period of only 4.27 years. The LCC of IDR 400.37 billion and the CoE of IDR 285.98/kWh indicate that this project can keep energy production costs at a competitive and sustainable level. This study concludes that Flare Gas Recovery to Electricity technology is the optimal solution to support zero flaring initiatives and make a real contribution to reducing flare gas emissions, as well as providing high added value in terms of economy and environment.

Introduction

The upstream oil and gas (oil and gas) industry in Indonesia plays a crucial role in contributing to national energy security (Winarto, 2021). As one of the largest natural resources, this industry not only provides vital energy for the community, but also becomes the main support for economic growth (Khalili-Garakani, Nezhadfard, & Iravaninia, 2022). In this study, attention to the implementation of the latest technology in the upstream oil and gas industry business process, especially in the use of flare gas which is currently still burned in the flaring system, becomes increasingly urgent (Putri & Rahmanida, 2023).

The oil and gas industry faces significant challenges as the world transforms towards a clean energy transition. One of the impacts is the large number of financial sectors that have stopped funding new oil and gas projects (Aripin, Prabowo, Haryanto, & Kumara, 2023). However, oil and gas demand is still growing, especially in developing regions such as India, Africa, and Asia, where economic growth, urbanization, industrialization, and the number of vehicles are predicted to increase significantly. Therefore, investment in oil and gas projects is still needed to provide energy security and meet the increasing demand for oil and gas, before renewable energy technology becomes more competitive (Soesanto, Angelicleatemia, & Julia, 2024).

The government also targets oil production of 1 million barrels and 12 BSCFD gas by 2030, with a focus on domestic utilization. Indonesia has 68 potential unexplored basins and proven oil reserves of 2.4 billion barrels, as well as proven gas reserves of around 43 TCF (Prasetyo & Windarta, 2022). To encourage upstream oil and gas investment, the government has made policy breakthroughs through contract flexibility, improvement of terms and conditions in oil and gas work area auctions, and fiscal/non-fiscal incentives. The government is also ready to revise the 2001 Oil and Gas Law to improve the investment and economic climate of oil and gas projects in Indonesia. IOG 2022 was held in a hybrid manner with the active participation of the Ministry of Energy and Mineral Resources, which participated in discussions and exhibitions related to the oil and gas industry (Amanda, Putri, Arifan, Hidayat, & Ikaningtyas, 2024).

On May 22 - 24, 2023, the special task force for upstream oil and gas business activities (SKK Migas) held a workshop on technology and gas utilization, which was initiated as a follow-up to the gas expo forum in 2022 (Manalu & Setyadi, 2010). The workshop covered various aspects, ranging from the implementation of gas technology, gas potential estimation, gas market absorption capabilities, to conversion methods from oil to gas. This workshop will also be a reflection of awareness of the importance of continuing to develop more efficient gas management technologies and strategies (Newnan, Eschenbach, & Lavelle, 2004).

Average emissions per facility also varied, with oil refineries having the highest emissions per facility of 1.15 million metric tons of CO_2. Accumulation and enhancement had average emissions per facility of 0.25 million metric tons of CO_2, followed by onshore production of 0.20 million metric tons of CO_2, natural gas processing and overall production of 0.13 million metric tons of CO_2, and offshore production of 0.05 million metric tons of CO_2 (Genc, Genc, & Goksungur, 2017). Of the total emissions, flare and blowdown vent emissions reached 36 million metric tons of CO_2, of which oil refineries and onshore production were the main contributors with 3.2 and 18 million metric tons of CO_2, respectively (Mian, 2011). The largest percentage of emission sources from flares and blowdown vents were found in offshore production (25.4%) and onshore production (19.3%).

The objectives of this research are as follows:

1. Identify the latest technologies that can be applied to improve efficiency and productivity in the upstream oil and gas production process.
2. Analyze the effectiveness of the implementation of the latest technology in minimizing flare gas emissions in the upstream oil and gas industry.
3. Develop a strategy to optimize the use of beacon gas in Indonesia's upstream oil and gas industry to support sustainable development goals.

4. Analyze/identify changes in business processes in the application of zero flaring technology.

Method

This research method will use the SWOT (Strengths, Weaknesses, Opportunities, Threats) and AHP (Analytical Hierarchy Process) approaches to analyze the potential implementation of beacon gas reduction technology in the oil and gas industry. A SWOT analysis will help identify internal and external factors that affect the success of the project, while AHP will give weight and priority to the various criteria involved in decision-making. In addition, economic analysis such as IRR (Internal Rate of Return), BEP (Break-Even Point), NPV (Net Present Value), and ROI (Return on Investment) will be used to evaluate the financial feasibility of this project. The data from this economic analysis will provide an overview of the potential benefits and risks of investment, helping companies determine whether these projects can provide significant added value.

The plan for new products such as electricity generated from the conversion of flare gas will be designed to meet the company's internal energy needs and can also be sold to the national power grid. The risk and economic feasibility assessment will include a comparative analysis between existing regulations and the technical aspects of the implementation of these technologies. This evaluation will consider various factors such as initial investment costs, operational costs, potential revenue, and the impact of applicable environmental regulations. Thus, the results of this method will provide a comprehensive view of the advantages and challenges of implementing flare gas reduction technology, as well as ensure that decisions are based on a holistic and informed analysis.

The data analysis techniques that will be used in this study are:

1. Qualitative analysis, such as thematic analysis and content analysis.
2. Quantitative analysis, such as economic and risk analysis.

Literature Studies

A literature study is needed to gain a thorough understanding of SWOT analysis, AHP, economic analysis, and risk evaluation as well as best practices in the use of the latest zero flaring technology that will be discussed in this study. Literature studies can be derived from academic literature, industry reports, and relevant case studies and analyze the findings of literature reviews to identify key concepts, theories, and methodologies. The purpose of the literature study is to be used as a comprehensive literature review that summarizes the current knowledge of the latest zero flaring technology with SWOT, AHP, economic analysis, and risk evaluation methods.

Data Collection

Quantitative data collection in this study will be carried out through various credible and relevant sources, including:

1. Annual Reports and Industry Statistics: Data from global energy agencies such as the International Energy Agency (IEA), U.S. Energy Information Administration (EIA), and the World Bank will be used to obtain statistics on flare gas volumes, oil production, and CO2 emissions from different regions and time periods. These reports provide detailed and reliable data on production and emission trends in the oil and gas industry.
2. Public Databases and Archives: Access to national and international databases such as the BP Statistical Review of World Energy, which provides historical and up-to-date data on oil and gas production, as well as flare gas emissions.
3. Company Case Studies: Empirical data from oil and gas companies that have implemented flare gas reduction technology, such as sustainability reports and case studies on the implementation of Flare Gas Recovery (FGR) technology.

Results and Discussion

Based on the results of data processing from 364 gas fields, it was found that the composition of the gas association produced has a fairly good methane (CH_4) content, so that it provides great potential to be used in various flare gas processing projects (Bahadori, 2014). The significant methane content in these fields shows the potential utilization of flare gas into energy, both in the form of electricity and fuel, in accordance with the Flare Gas Recovery (FGR) technology proposed in this study.

Table 1

Gas Content and Gas Calorific Value

Field	NHV/LHV (dry, real gas) [BTU/SCF]
Red Field 39	1102
Red Field 57	1055
Blue Field 5	1004
Blue Field 11	1437
Blue Field 13	1192
Blue Field 41	1123
Blue Field 42	1115
Green Field 41	1473
Black Field 6	1158
Black Field 8	1305
Black Field 9	1253
Black Field 10	1213
Black Field 11	1184
Black Field 22	1007
Black Field 24	1011

Black Field 28	1235
Black Field 32	1033
Black Field 58	2200
Yellow Field 9	1281
Yellow Field 23	1063
Yellow Field 48	1046
Yellow Field 53	1089
White Field 15	1654
White Field 16	1680
White Field 25	1013
White Field 33	1041
White Field 34	1195
White Field 35	1106

The results of data processing from 364 gas fields in Appendix 1, are presented in Table 1 for several fields that have a calorific value above 1,000 BTU/SCF. In this case, it is interpreted that the higher the calorific value, the higher the potential for electricity capacity produced (Aoun et al., 2024). Therefore, these fields have very good potential to be utilized into electrical energy or fuel. This is also supported by a reference to the gas specifications listed in Table 2.

Table 2

Typical Pipline Gas Specification (Handbook of Natural Gas Transmission and Processing, 2015)

Characteristic	Specification
Water content	4-7 lbm H2O/MMscf of gas
Hydrogen sulfide content	0.25E1.0 grain/100 scf
Gross heating value	950-1200 Btu/scf
Hydrocarbon dewpoint	14-40 F at specified pressure
Mercaptans content	0.25-1.0 grain/100 scf
Total sulfur content	0.5-20 grain/100 scf
Carbon dioxide content	2-4 mol%
Oxygen content	0.01 mol% (max)
Nitrogen content	4-5 mol%
Total inerts content (N2 + CO2)	4-5 mol%
Sand, dust, gums, and free liquid	None
Typical delivery temperature	Ambient
Typical delivery pressure	400-1200 psig

However, in addition to the high methane content, some fields also show the presence of impurities in the form of acid gases such as carbon dioxide (CO_2) and hydrogen sulfide (H_2S). This impurity content requires an additional purification process before the gas can be utilized optimally. This purification process is important to increase the efficiency *of zero flaring* technology to be applied and minimize the environmental impact of toxic gas emissions.

In Table 3, it is found that the composition of the resulting gas association has a high content of impuritis and impurities. Among them are H2S Gas, CO2, and Moisture. With the content of impurity gases and water, the flare gas that will enter the FGR technology must be processed first to separate H2S, CO2, and Moisture gases.

Table 3

Gas Content of H2S, CO2, and Moisture

Field	Carbon Dioxide [%(mole)]	H2S content [ppm]	Moisture Content [Lbs/MMSCF]
Red Field 4	70,69	1100	15
Red Field 7	65,45	250	15
Red Field 8	59,25	50	15
Red Field 59	62,26	290	15
Red Field 60	76,37	250	15
Blue Field 1	52,63	1	15
Blue Field 2	53,79	130	15
Blue Field 3	52,53	100	15
Blue Field 38	71,8	25	15
Green Field 26	55,61	25	15
Black Field 12	79,67	14	15
Black Field 14	61,59	100	15
Black Field 15	73,67	100	15
Black Field 18	67,82	50	15
Black Field 19	58,57	50	15
Black Field 20	66,94	2000	15
Black Field 21	71,57	320	15
Black Field 26	53,99	400	15
Black Field 27	60,53	60	15
Black Field 29	80,91	140	15
Yellow Field 48	64,84	100	15
Yellow Field 52	94,2	200	15
White Field 14	56,34	300	15
White Field 15	58,84	100	15
White Field 21	54,61	150	15
White Field 30	74,55	110	15
White Field 31	65,21	600	15
White Field 38	79,31	75	15
White Field 39	79,07	150	15

White Field 40	65,1	125	15
White Field 41	61	195	15
White Field 42	54,08	30	15
White Field 43	63,95	520	15
White Field 44	61,32	600	15
White Field 52	57,51	7	15
White Field 55	62,45	100	15
White Field 56	61,96	100	15

The removal of H_2S from flare gases through the purification process also offers additional benefits, namely producing sulfur as an economically valuable by-product and can be used as a feedstock in the chemical industry (Kohl & Nielsen, 1997). This step not only reduces contaminants that lower the calorific value, but also creates additional revenue potential from by-products. On the other hand, the use of *Carbon Capture, Utilization, and Storage (CCUS)* technology to manage CO_2 separate from the gas stream can support efforts to reduce carbon emissions, while maintaining the purity of methane needed to achieve high generation efficiency.

Thus, the use of purification technology in the processing of flare gas not only allows for increased value, but also strengthens the sustainability aspect from an environmental and economic perspective. The utilization of previously wasted flare gas, through an increase in the calorific value generated from refining, shows that *Flare Gas Recovery technology* can be optimized as an effective step in supporting energy efficiency and emission reduction in the upstream oil and gas industry.

In addition, the calorific value of the gas produced from each field varies, indicating the potential for different energies from one field to another that will merge into multiple gathering *stations*. This difference in calorific value will be an important consideration in determining the most suitable type of project and technology to implement at each collection station.

With the gas association profiles identified, this chapter will continue the discussion related to project and development options that can support the implementation of *zero flaring technology*. This evaluation was carried out to maximize the energy potential of flare gas and reduce emissions, in line with the goal of reducing flaring in the upstream oil and gas industry.

Interview Results

Interviews conducted with 3 (three) expert resource persons provided diverse insights related to the processing operations of gas associations that are currently still burned in flares. Although each resource person has a different approach in technical and strategic views, they all have the same goal, which is to minimize flare gas emissions through the application of zero flaring technology. This diverse approach reflects the complexity and challenges of selecting the most suitable project alternatives to be implemented in existing gas fields.

One of the speakers emphasized the reliability of the current operation, where the use of flares is considered an efficient solution in the short term to deal with excess gas. However, he also acknowledged that long-term sustainability requires investment in more environmentally friendly and economical technologies. Other speakers highlighted the need to improve infrastructure and develop highly competent human resources to manage new technologies such as Flare Gas Recovery (FGR). Meanwhile, the third speaker focused on the regulatory aspects and policy support needed to encourage the implementation of zero flaring technology, especially in facing economic and technical challenges.

Although each speaker provided a different point of view, they agreed that each planned alternative project has its own strengths and weaknesses. The reliability of current operations must be carefully considered in determining the right solution, both in terms of the technology to be used and in planning for the future of flare gas management. The results of this interview provide an overview that the selection of project alternatives must consider not only technical reliability, but also alignment with the long-term vision in supporting emission reduction through zero flaring.

Alternative Analysis of *Zero Flaring Technology Selection*

In this evaluation, an alternative approach and selection are used that are generally carried out in each oil and gas project at the pre-FEED (*Prelimenary Front End Engineering Design*) stage. This approach aims to identify and select the most suitable technology based on technical, economic, and environmental criteria. The pre-FEED stage is an important step in determining the overall feasibility of the project before proceeding to further studies and the detailed design and implementation stages.

Table 4
Alternatives and Selection of Zero Flaring Technology

Criterion	FGR to Electricity	FGR to Fuel (LNG/CNG)	FGR Reinjection	FGR to LPG
Operational Reliability	High, stable for internal energy requirements	Medium, requires distribution infrastructure	Moderate, maintaining reservoir pressure	Moderate, requires additional purification
Cost	High, large initial investment but potentially quick payback	High, transportation and storage costs	Medium, the initial investment is high, and the operational	Meanwhile, the processing process is

			costs are also high	more expensive
Regulatory Aspects	Support, in accordance with zero flaring policy	Supports, but requires distribution permission	Supporting, part of energy conservation programs	Support, depending on the LPG market
Complexity of Technology	Medium, requires turbine and generator technology, but implementation is quite common in the industry	High, requires gas liquefaction facilities	Medium, existing gas injection technology	Meanwhile, the gas separation process is more complicated
Potential Emission Reduction	Very high, eliminates gas flares completely	High, reducing emissions from gas combustion	Meanwhile, gas remains stored in the reservoir	High, gas converted to LPG
Implementation Time	Medium, requires the construction of new facilities, but can be integrated with existing operations	Long, requires the development of LNG/CNG infrastructure	Medium, small additional infrastructure	Medium, requires additional facilities
Economic Benefits	High, energy can be sold or used	High, large fuel market potential	Maintaining oil and gas production	High, LPG has economic value

Based on the evaluation carried out, the technology for utilizing flare gas into electrical energy was chosen as the best alternative to be applied in gas processing in the fields studied. The use of gas into electrical energy was chosen because this technology was considered the most suitable for the gas association conditions produced from the 364 fields analyzed. In addition, this technology offers advantages in terms of operational reliability, potential energy savings, as well as a significant contribution to the reduction of flare gas emissions, in line with the goal of zero flaring.

AHP Analysis

In the AHP (Analytical Hierarchy Process) method, each alternative is assessed based on several key criteria, such as operational reliability, cost, regulation, complexity, potential emission reduction, and economic benefits. Each criterion is weighted based on its level of importance, then a pairwise comparison assessment is carried out to determine technology priorities. Here are the weights and results of the AHP analysis:

Table 5
AHP *Zero Flaring Technology*

Criterion	Weight	FGR to Electricity	FGR to Fuel (LNG/CNG)	FGR to Reinjection	FGR to LPG
Operational Reliability	0.30	0.90	0.75	0.80	0.70
Cost	0.25	0.70	0.60	0.65	0.60
Regulation	0.20	0.85	0.80	0.70	0.75
Complexity of Technology	0.10	0.75	0.65	0.70	0.60
Potential Emission Reduction	0.10	0.95	0.85	0.65	0.80
Economic Benefits	0.05	0.90	0.80	0.70	0.85
Relative Weight		0.835	0.735	0.715	0.720

FGR to Electricity (0.835) has the highest relative weight because it scores higher in critical aspects such as operational reliability, potential emission reductions, and economic benefits, although the initial cost and complexity are quite high. FGR to Fuel (LNG/CNG) (0.735) is in second place, because its economic potential is high, but the cost and complexity are greater. FGR to LPG (0.720) scored third with an advantage in the LPG market and emission reduction, but its complexity and processing costs were factors in the relative weight reduction. FGR Reinjection (0.715) is ranked last because although it maintains reservoir pressure, this technology has limitations in emission reduction and economic benefits compared to other options.

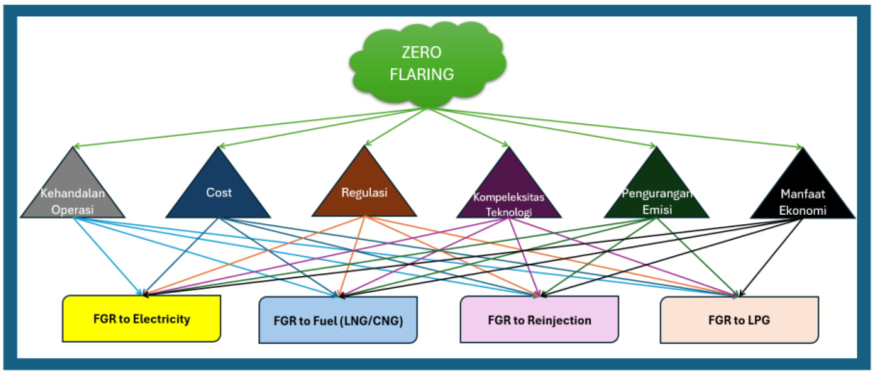

Figure 1
AHP Analysis Hierarchy Diagram

In Figure 1, the AHP Analysis hierarchy diagram shows the structure, criteria, and alternative selection of technologies for beacon gas treatment. This diagram presents three levels: the main objectives, the main criteria, and the technological alternatives, which provide an overview of the relationships between the elements used in the decision-making process.

Based on the results of AHP analysis, *FGR to Electricity* has the highest relative weight, which makes it the best alternative to implement. This technology not only supports *zero flaring* policies, but also has the most significant economic benefits and emission reduction potential.

Financial Analysis

In this section, a financial analysis is carried out to evaluate the feasibility of the project of utilizing flare gas into electrical energy through the calculation of three main parameters: Net Present Value (NPV), Internal Rate of Return (IRR), Benefit-Cost Ratio (BCR), payback period (PBP), Life cycle cost analysis (LCC), and Cost of Energy. These six parameters are used to assess whether the investment in the project can provide a decent return, as well as to determine the level of profitability of the project in the long term.

Net Present Value (NPV)

The NPV calculation is done to find out whether the project provides positive added value after taking into account the cash flow generated over the life of the project and subtracting it from the initial investment.

In this analysis, it is assumed that the value of the initial investment project is Rp 350 billion with a power generation capacity of 10 megawatts. This project is planned to operate for 20 years with an electricity price of Rp 1,300 per kWh. The discount rate used is 20%, while operational and maintenance (*O&M*) costs are estimated at 10% of the total annual revenue generated from electricity sales.

NPV = $C_0 + \sum_{t=1}^{n} \frac{C_t}{(1+r)^t}$

Where:

C0: initial investment (Rp. 100 billion)

Ct: annual operating expenses (Rp. 81.9 billion)

R: Discount rate (20% or 0.2)

N: Project lifespan (20 years)

Assumptions (base)

Project Value (Initial Investment): IDR 100 Billion

Electricity Generated Capacity: 10 Megawatts (MW)

Electricity Price: Rp 1,300 per kWh

Discount Rate: 20%

Project Lifespan: 20 years

Number of Operating Hours per Year: 7,000 hours (operational assumptions per year)

Operating and Maintenance (O&M) Expenses: 10% of revenue per year

Annual Revenue:

Annual Electricity Production: 10 MW × 7,000 hours = 70,000 MWh

Revenue per Year: 70,000 MWh × Rp 1,300/kWh = Rp 91 Billion per year

Operating Expenses (O&M): 10% × Rp 91 Billion = Rp 9.1 Billion per annum

Annual Net Cash Flow: Revenue – O&M Expenses = IDR 91 Billion – IDR 9.1 Billion = IDR 81.9 Billion

The NPV calculation shows a positive value, which indicates that the cash flow of this project can cover the entire investment cost and generate added value for the company in the long run. In addition, the IRR rate obtained is higher than the discount rate used, indicating that the project will provide an attractive rate of return for stakeholders. A BCR greater than 1 also shows that the financial benefits of the project outweigh the costs. A PBP of 4.27 years indicates a very short payback time. The PBP indicates that the initial investment will return in about one year and three months, which indicates the low financial risk of the project and the rapid acquisition of positive cash flow. The LCC of Rp 400.37 billion shows that this project is not only profitable but also has controlled costs in the long term. The CoE of Rp 285.98 per kWh shows that the energy production cost of this project is very low, far below the average electricity market price. This low CoE signifies that the project is able to generate electricity at a very competitive cost, which can provide large operational cost savings or even generate additional revenue if electricity is sold to the grid.

With the results of this positive economic analysis, gas conversion technology into electrical energy is considered to be able to be implemented efficiently in the gas fields that have been studied. This project not only helps to minimize flare gas emissions through the implementation of zero flaring, but also provides economic benefits that can improve overall operational efficiency. Therefore, from a technical and financial perspective, this technology is considered feasible to be adopted in supporting the sustainability of the upstream oil and gas industry.

Conclusion

The application of Flare Gas Recovery (FGR) to electricity technology is an effective solution to support zero flaring in the upstream oil and gas industry, by converting flare gas into electrical energy that can be used for the company's operational needs. This technology not only significantly reduces carbon emissions, but also creates economic added value through by-products, such as sulfur from H_2S purification that can be utilized in the chemical industry, and carbon sequestration potential through Carbon Capture, Utilization, and Storage (CCUS) technology for CO_2. In addition, FGR to electricity supports operational efficiency by utilizing exhaust gas that was previously wasted. While it requires large initial investments and adjustments to infrastructure and workforce competencies, the technology offers long-term benefits, including energy savings, reduced greenhouse gas emissions, and improved environmental sustainability. Overall, this technology not only supports the company's sustainability initiatives, but also has a positive economic and environmental impact.

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