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ARTICLE

Compressing Natural Gas - Carbon Capture EOR (CAGAR) Innovation: Cost Effective Sustainable Flare Gas Utilization to Boost Oil Production

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Abstract: Drilling natural gas (CNG) is a promising environmentally friendly gasoline substitute. It is produced at a reasonable price. Flaring, on the other hand, emits 300 million tons of CO2 into the environment wasting vital energy resources. As a result, rather than releasing CO2 into the atmosphere, it is used to boost oil production as a CO2 EOR to fulfill global oil demand that continues to rise. To achieve a sustainable oil and gas production by reducing greenhouse gasses (GHG) through flaring reduction innovations comprising gas purification and carbon capture that utilizes the associated gas as a viable compressed natural gas (CNG) and enhanced the oil recovery. Natural gas linked with crude oil (CH4 dominated) is processed in two units. The first one is a gas purification unit where natural gas is purified in compressor, Acid Gas Removal Unit (AGRU), dehydration unit, and hydrocarbon recovery producing viable CNG. In the flaring unit gas is burned converting the CH4 to CO2. Flared gas is captured in a Carbon Capture Storage (CCS). Furthermore, CO2 is centralized in the EOR-System to be injected into the reservoir as CO2-EOR by interacting with oil causing oil to swell and reduce its viscosity leading to oil flow easier through the pores. This research elucidates that CAGAR could produce 2,970 mmbtu/d of CNG. Beside producing profitable products, CAGAR also boosted oil production by adding an extra 21,369.6 bbl/d oil recovery. According to the results, the production of the CAGAR method of flare gas utilization is the most economical technology with an annual sales from oil recovery and CNG of 455,768,373 USD so that CAGAR get a profit before tax of 248,288,632.81 USD and a profit after tax of 207,479,740.57 USD with a parameter calculation is a positive NPV, IRR of 30.26% including the cash flow and present value start to be positive in the 3rd year when the system starts operating. CAGAR has a payback period of 2.7 years. Technical and economic analysis shows there improved oil recovery and improved environmental protection. So it can be concluded that CAGAR has good prospects and deserves to be implemented.

Keywords: Carbon Capture Storage, Economic Analysis, Flaring, Natural Gas, Oil Production

1. Preliminary

Compressing Natural Gas - Carbon Capture - EOR (CAGAR) is needed to solve the emission problems. Gas flaring is one of the world's most serious issues. It depletes natural resources and generates hazardous waste, both of which have severe consequences for society. It's one of the world's most vexing energy and environmental issues right now. It is a multibillion-dollar waste, a local environmental catastrophe, and a decades-old environmental crisis. In recent years, the amount of gas flared globally has increased, and the world now flares as much as it did ten years ago. It is mentioned by IEA that in 2020, 142 billion cubic meters of natural gas were flared globally, approximately equal to Central and South America's natural gas demand which resulted in the direct emission of over 265 Mt CO2, nearly 8 Mt methane (240 Mt CO2-eq), black soot, and other GHGs into the atmosphere. As a result, flaring reduction is required and critical.

Over and above that, oil and gas industry plays a critical and dynamic role in the global energy grid that the demand continues to rise. EIA forecasted that in 2022, global oil demand will reach 100.5 million barrels per day, rising to 102.3 million barrels per day in 2023. Gas demand also expected to rise by a third over the next 30 years, to roughly 5300 bcm by 2050 (BP, 2018). What is interesting is that compressed natural gas (CNG) is here as a promising environmentally friendly gasoline substitute that produced at a reasonable price.

Therefore, as an innovative we propose the technology namely Compressing Natural Gas - Carbon Capture - EOR (CAGAR), as a result, CAGAR ability to increase oil recovery from compressed natural gas (CH4 dominated) and can produce the viable CNG.

In this paper, we briefly discuss Compressing Natural Gas - Carbon Capture - EOR (CAGAR) technology as a form of innovation in this energy and environmentally friendly on energy transition period. We then explain some process about compressed natural gas to increase oil recovery. We then explain an economic analysis of ULIN technology based on the parameters of NPV, IRR and payback period.

A. Flaring Reduction

" ...an arrangement of piping and a burner to dispose of surplus combustible vapours...” is how flare is defined (Tver and Berry, 1980). Elevated flares, which are towering, chimney-like structures with visible flames at the top, are most usually found surrounding a gasoline plant, refinery, or producing well (Indriani, 2005). Flaring is the act of burning associated gas. During the drilling and testing of oil and gas wells, as well as during emergencies, equipment failures, and maintenance shutdowns, gas flaring occurs. In essence, the massive volume of gas released could be employed for more productive reasons, such as electricity generation. Flaring is hence a waste of resources and needed to be reduced. Here proposed the flaring reduction mechanism by processing natural gas into other resource before flared and processing the flared gas to enhance oil production.

B. Compressed Natural Gas

Compressed Natural Gas (CNG) is natural gas that has been compressed at a high pressure. The primary components of CNG are methane (CH_3) and ethane (C_2H_8), which make up around 90% of the total (Pujotomo, 2018). The composition of CNG is detailed in Table 1. When forced to 1400 psig, the volume of natural gas will be 1/133 times that of when pressed to 2850 psig (Nafiscatoha & Saksono, 2019). The goal of this compression is to transport a larger volume of natural gas than would be possible without the liquefaction process. CNG is stored and distributed through the packaging in the tank.

C. Gas Purification

Gas purification entails the removal of vapor-phase contaminants from gas streams. Gas purification procedures range from basic once-through wash operations to complicated multi-step recycle systems (Kohl & Nielsen, 1997). The requirement to recover the impurity or reuse the material used to remove it is often the source of process complexity. Purification of the gas feed is done according to the parameters and composition of the gas feed. The CO2 content in the feed gas is the focus of gas purification in this scenario. The CO2 level of 15.4% in the feed gas necessitates first purification for CO2 and H2S removal. The goal CO2 level must be decreased to less than 0.005 mol% or 50 ppmv. The detail of feed gas composition is shown in Tabel 2.

2. Research Methods

Technical Description

CAGAR offers an innovative solution in order to reduce flaring by processing feed gas in gas purification into CNG and utilizing flared gas to be used in CO2 EOR. The system design of CAGAR is demonstrated in Figure 1.

Natural gas, which in this paper is determined as flare gas, is processed in two units. The first one is gas purification. Flare gas is made by both associated and non-associated gases and mixed to be feed gas. The feed gas is then compressed to a desired pressure in a compressor. Later, the feed gas is then treated in an Acid Gas Removal Unit (AGRU) to remove CO_2 and H_2S, resulting in sweet gas. Afterward, sweet gas is processed in a dehydration unit since the AGRU process creates sweet gas with a higher water content that needs to be lowered. The last step is to treat the gas in hydrocarbon recovery. Hydrocarbon recovery aims to separate CNG, which is dominated by methane and ethane, from other hydrocarbon compositions. To

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get an overview of gas purification, Figure 2 has been provided.

Apart from processing flare gas in gas purification unit, flare gas then flared in flaring unit. In the flaring unit gas is burned converting the CH_4 to CO_2. CO_2 is captured in a Carbon Capture Storage (CCS). Furthermore, CO_2 is centralized in the EOR-System to be injected into the reservoir as CO_2-EOR. This CO_2 is routed to injection wells that are purposefully located inside the well pattern to maximize the reservoir's areal sweep. The CO_2 is injected into the reservoir and flows through the pore spaces of the rock, colliding with leftover crude oil droplets, becoming miscible with the oil, and generating a concentrated oil bank that is swept towards the producing wells.

3. Results and Discussion

CNG product with a flow rate of 3,204 mmscfd, a temperature of 35.56°C, and a pressure of 2901 psia was obtained. Furthermore, it is found that injection of 1 tonne CO_2 could produce 2 bbl of oil recovery. By this scheme, 10.903 tonne/day of CO_2 is injected to the reservoir resulting 21.369,6 b/d oil recovery.

Economic Result

Economic analysis is performed to assess the economic feasibility of the system. This study considered net present value (NPV), internal rate of return (IRR), fixed capital (FC), and payback period ($t_{payback}$) as the economic performance indicators. These indicators are calculated by developing cost functions of each component in the system along with the assumptions as mentioned in Table 3 based on literature studies of the research by Bachtiar et al. (2021), Mwagomba (2016), and Kesieme et al. (2013).

A project or system is feasible if the NPV is positive. NPV is formulated below (Bachtiar et al., 2021), where it is the discount rate, t is the project life in years, and CF_t is the cash flow in the T-th year:

$$\text{NPV} = \sum_{T=0}^{T} CF_T/(1+i)^T \quad (1)$$

IRR is the discount rate that makes total present value equal to fixed capital (Achinas & Euverink, 2019). A project is feasible if the IRR is equal to or higher than the expected return. Fixed capital consists of equipment costs and additional costs, such as construction and project management costs, which are assumed to be 65% of total equipment cost. The payback period calculation includes construction duration, FC, additional net power output after implementing the proposed system (Wadd), OPEX, tax, and the sales income which are formulated as follows (modified from Noroozian et al., 2017):

$$t_{payback} = t_{construction} + \frac{FC}{(Sales - OPEX) \times (100\% - TAX\%)} \quad (2)$$

$$\text{Sales} = m_{oil} \times c_{oil} \quad (3)$$

This study performed an economic analysis for the proposed system to assess its feasibility from the economic point of view. From the economic analysis, the fixed capital, NPV, IRR, and payback period of the proposed system are obtained as can be seen in Table 4. These economic parameters are used to decide whether the system is economically feasible. In addition, the cumulative cash flow profile of the proposed system can be seen in Figure 3, which is used as the basis of calculation of NPV and IRR.

The amount of fixed capital needed to develop the proposed CAGAR system is USD 155,609,805.43. The project yields a positive NPV of USD 663,472,878 with the IRR of 30.26%. Furthermore, the payback period is 2.6 years calculated since the beginning of the project or 4 years after finishing the construction phase. The positive NPV, high IRR, and short payback period show that the proposed system is economically feasible to implement.

4. Conclusions

The ability to increase oil recovery and produce viable CNG from some process, CAGAR approach is a simple and effective method of providing oil recovery reinforcementin the transition energy era.

We present some results to demonstrate the benefits of using CAGAR technology:

a. CAGAR will produce CNG product with a flow rate of 3,204 mmscfd, a temperature of 35.56°C, and a pressure of 2901 psia.
b. CAGAR will injection of 1 tonne CO_2 could produce 2 bbl of oil recovery. By this scheme, 10.903 tonne/day of CO2 is injected to the reservoir resulting 21.369,6 b/d oil recovery.
c. Economic analysis showed that the NPV and IRR of the proposed system are USD 663,472,878 and 30.26%, respectively, with a payback period of 2.7 years. The positive NPV, high IRR, and short payback period indicates that the proposed system is economically feasible to implement.

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Tables and Figures

Table 1. Composition of CNG (Nafiscatoha & Saksono, 2019)

Composition	Mole Fraction of CNG (mol%)
H_2S	0
CO_2	0.0644
N_2	1.14
Methane	87.66
Ethane	10.1
Propane	1
i-Butane	0
n-Butane	0
i-Pentane	0
n-Pentane	0
Hexane +	0
H_2O	0.017

Table 2. Composition of Feed Gas (Nafiscatoha & Saksono, 2019)

Composition	Mole Fraction of CNG (mol%)
H_2S	0
CO_2	15.4025
N_2	0.8325
Methane	69.03
Ethane	5.92
Propane	5.1075
i-Butane	1.1525
n-Butane	1.3125
i-Pentane	0.4475
n-Pentane	0.315
Hexane +	0.48
H_2O	0.017

Figure 1. CAGAR System Design

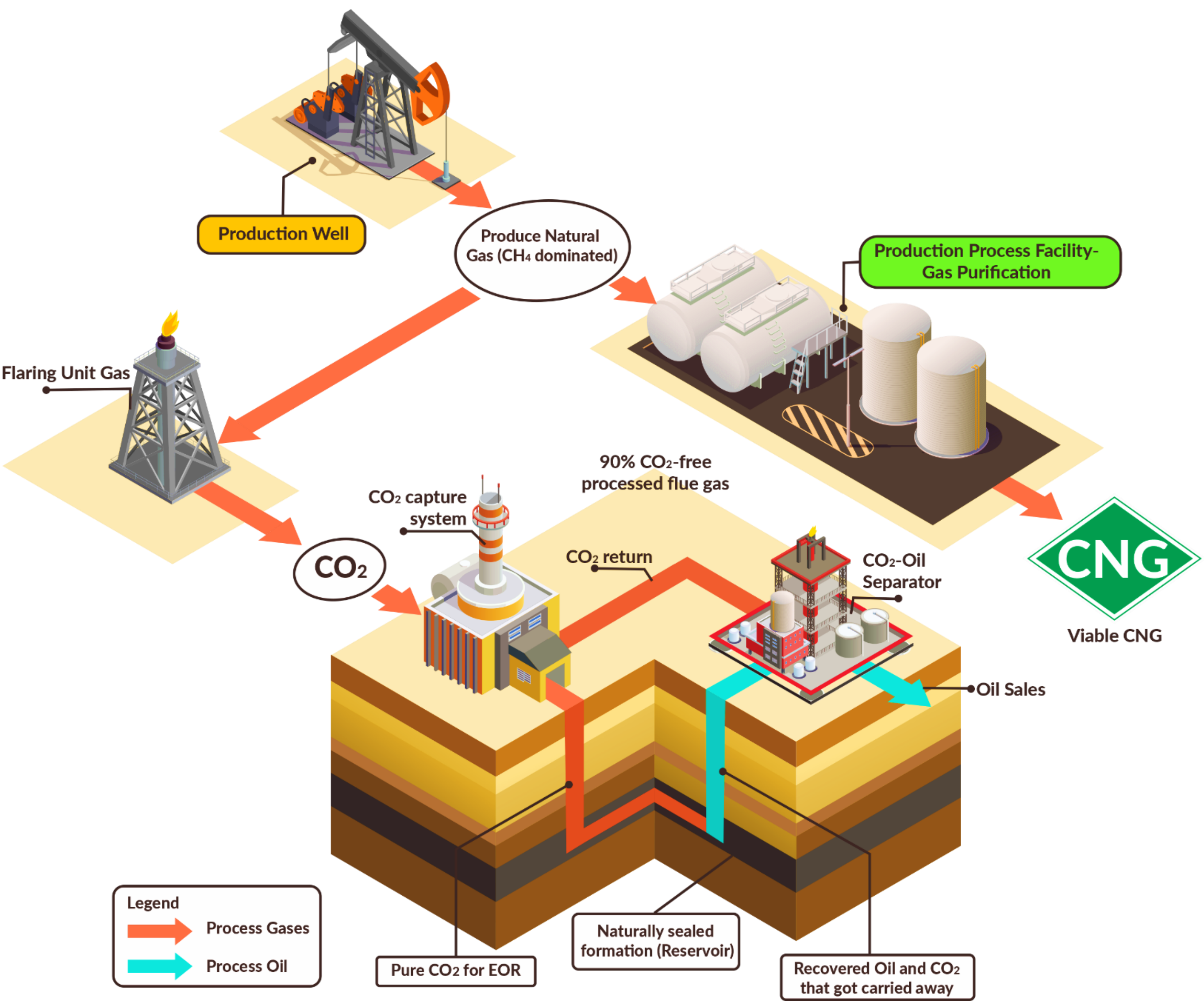

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Figure 2. Gas Purification Process

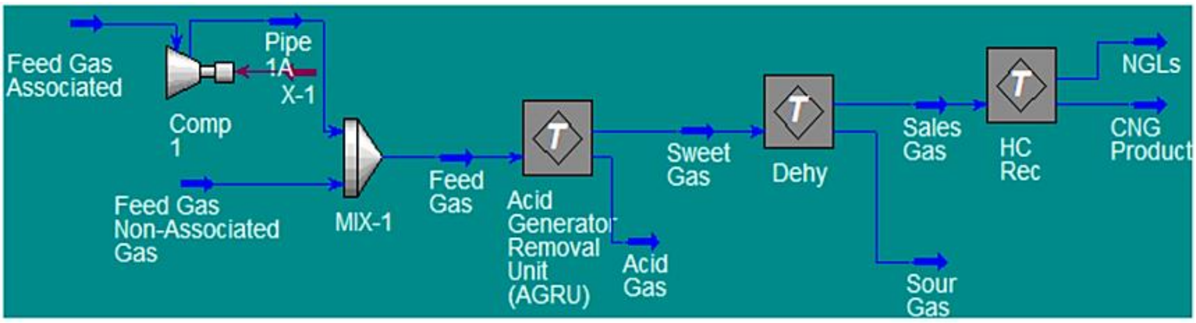

Table 3. Basic financial assumptions used for economic analysis.

Parameter	Value	Unit
Project duration	20	Year
Discount	10	%
Tax	25	%
Construction duration	3	Year
Fixed capital distribution for construction phase first, second, and third year	20/30/50	%
Operating expenditure (OPEX)	50	% modal
Cost of Gas Purification	40,500	USD
Cost of CO2 Injection Compressor	20,083,000	USD
Cost of Combution Carbon Capture	151,079,266	USD
Cost of Oil (C_{Oil})	60	USD/bbl

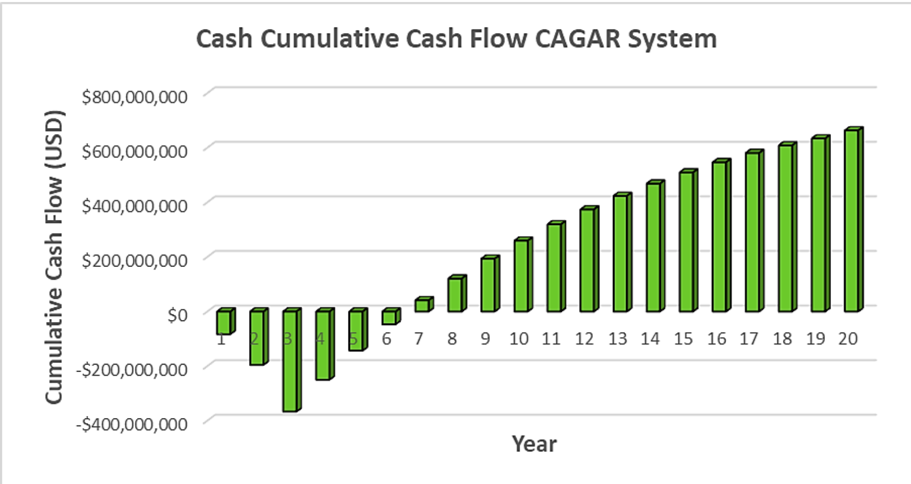

Figure 3. Cumulative cash flow of the proposed system.

Table 4. Results of economic analysis.

Economic parameter	Unit	Value
Fixed capital	USD	155,609,805.43
NPV	USD	663,472,878
IRR	%	30.26
Payback period	Year	2.7

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