European Journal of Business and Management Research
Vol 9 | Issue 2 | April 2024
ISSN 2507-1076

CASE STUDY

Utilization of Biomethane to Support Energy Security in Indonesia, Riau Province: A Case Study

Ali Fahrudin*, Dzikri Firmansyah Hakam, and Widhyawan Prawiraatmadja

ABSTRACT

As the largest global palm oil producer, Indonesia contributes 59% to the world's palm oil supply, producing 46.9 million tons of Crude Palm Oil (CPO) in 2021. However, this extensive production poses an environmental challenge through Palm Oil Mill Effluent (POME), estimated at 156 million m^3 annually. POME treatment facilities release Biogas, predominantly Methane (CH_4) at 50%–75%, a potent Greenhouse Gas (GHG) with 21 times the global warming potential of CO_2. Conversely, Methane is a key component of widely used Natural Gas. Properly treated, POME-derived biogas can be upgraded to Biomethane, a clean and carbon-negative alternative for the Natural Gas Grid or fossil fuel substitution, estimated at 1,280 MWe, equivalent to 288 MMSCFD CH_4. Despite Biomethane's potential, its utilization remains limited to self-use in Palm Oil Mills or power plants, even in Riau Province, home to Indonesia's largest oil palm plantation. PT Perusahaan Gas Negara Tbk survey identified potential customers in Riau willing to adopt natural gas, hindered by infrastructure and economic scale challenges. This research analyzes obstacles to biomethane business development in Indonesia, focusing on Riau Province, aiming to formulate an optimal distribution scheme and sustainable strategies. Methodologically, a mix of quantitative and qualitative data collection techniques, including literature studies, interviews, and questionnaires, informed a comprehensive analysis employing geographical, transportation cost, financial modeling, SWOT, and risk analyses. Findings suggest trucking as the optimal distribution mode for biomethane to scattered customers. Economic viability hinges on biomethane volume, necessitating stability and increased sales volume strategies. For Riau, four potential customers with a total daily demand of 11,248.93 m^3 can be served affordably by selecting palm oil mills within a 76 km radius. Price and security supply considerations are crucial. This research provides insights into overcoming challenges and optimizing the biomethane business in Riau, offering a sustainable model for broader adoption in Indonesia.

Keywords: Biomethane, Financial Modeling, Spatial Analysis, SWOT Analysis.

Submitted: January 17, 2024

Published: April 20, 2024

10.24018/ejbmr.2024.9.2.2281

School of Business Management, Institut Teknologi Bandung (SBM ITB), Indonesia.

Corresponding Author:
e-mail: ali_fahrudin@sbm-itb.ac.id

1. Introduction

The enhancement of renewable energy is one of Indonesia's guiding pillars in the energy sector to fulfill the Paris Agreement mandates. One type of renewable energy is Biomethane, a gas resulting from a process that improves biogas quality by reducing carbon dioxide, hydrogen sulfide, moisture, and other gases (Koonaphapdeelert *et al.*, 2020). Biomethane can be derived from palm oil mill waste, called POME (Palm Oil Mill Effluent).

Indonesia is the largest palm oil producer in the world, with a total Crude Palm Oil (CPO) production in 2021 of around 46, 9 million tons/year (Gabungan Pengusaha Kelapa Sawit Indonesia, 2021). This amount of production resulted in around 156 million m^3/year of POME (Udin & Agus, 2018). According to Winrock International (2015), the potential for POME in Indonesia that can be converted into energy is 1,280 Mwe, equivalent to 288 MMSCFD CH_4.

Currently, Biomethane's potential utilization in Indonesia remains limited to self-use in Palm Oil Mills or power plants, even in Riau Province, home to 19,5% of Indonesia's oil palm plantation area (Badan Pusat Statistik Indonesia, 2022), even though Biomethane can be used as an alternative source of clean and carbon-negative gas in the Natural Gas Grid or as a substitution for other fossil energy. PT Perusahaan Gas Negara Tbk, Indonesia Gas Transmission and Distribution Company survey indicates untapped potential gas customers in Riau Province within the industrial and commercial segments, currently relying on LPG and HSD. The unavailability of natural gas in the region creates a niche for biomethane to fulfill the energy needs of these potential customers. Several challenges complicate this endeavor:

- The unexplored use of biomethane as a traded fuel for commercial and industrial customers in Indonesia.
- Variation in biomethane production from each palm oil mill based on FFB production fluctuations, POME COD content, and the POME conversion rate to CH_4.
- The integrated location of palm oil mills within oil palm plantations, often distant from commercial and industrial centers, presents challenges in establishing an optimal biomethane supply chain for potential customers.

These challenges give rise to a pressing business issue: establishing a sustainable, easily accessible supply of biomethane with competitive and affordable prices compared to other fossil fuels in the market. Addressing these challenges is crucial for the successful integration of biomethane into the energy landscape of Riau Province, unlocking its potential as a viable alternative for the industrial and commercial sectors. To study these challenges, the scope of this research is limited to selecting the optimal biomethane transportation method from the biomethane factory to the potential customer, and the business strategy formulation concerns potential customer expectations in Riau Province based on quantitative and qualitative data.

2. Materials and Method

2.1. Supply Chain

Supply Chain Management (SCM) is critical in bioenergy production processes (Gold & Seuring, 2011). Biomass energy supply chain differs from traditional supply chains in several ways. Among them are the seasonal availability of agricultural biomass, low energy density, and uncertain energy production performance, which have implications for transport and storage (Iakovou *et al.*, 2010). The biomethane supply chain to the end user can be described in Fig. 1.

This research will focus on optimizing transportation issues. Gold and Seuring (2011) stated that the transportation issues within the bio-energy chain (Gold & Seuring, 2011) are divided into:

1) The legal and infrastructural framework: Biomethane is a flammable gas. One item that should be highlighted is a permit from the government to handle this flammable gas and limitation vehicle size correlated to road class.
2) Main variables impacting transport operations: The economic variable of transport is the distance correlated to the chosen routes from the biomethane plant to the end customer and the carrier type selected based on the customer demand. They will affect traveling time, capital cost, and energy consumption cost.

2.2. Biomethane Potential Customer

Biomethane can produce a maximum output temperature of up to 1000 °C (BloombergNEF & WBCSD, 2021). Thus, biomethane has a broader application for industrial and commercial heat processes, feedstock to produce derivative products, and electricity. To use biomethane, each customer needs to install a pressure-reducing system, and if its existing fuel system uses LPG or diesel fuel, the current fuel system needs modification. Therefore, if the demand is high, it will be comparable with the investment required. Amartya and GIZ (2022) stated that potential customers with gas demand below 1000 m^3/month do not have economic benefits.

2.3. Research Method

This research will be delivered with a conceptual framework in Fig. 2.

Based on the potential natural gas customers and palm oil mill locations in Riau Province, the nearest palm oil mills as biomethane sources from these potential customers will be identified using spatial analysis. Transportation costs are calculated using pipeline or CNG cylinders (trucks) to obtain the cost profile of each

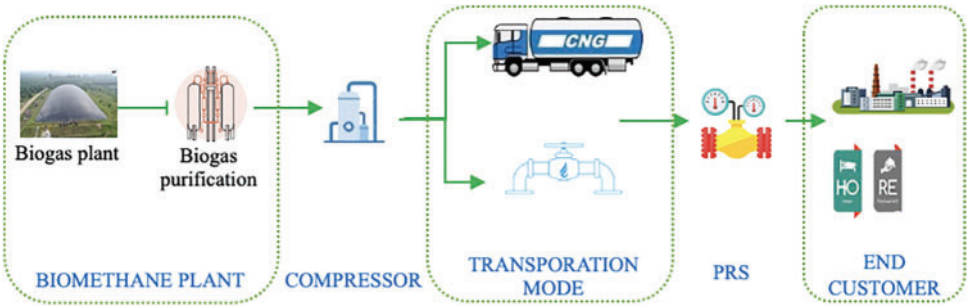

Fig. 1. Biomethane supply chain.

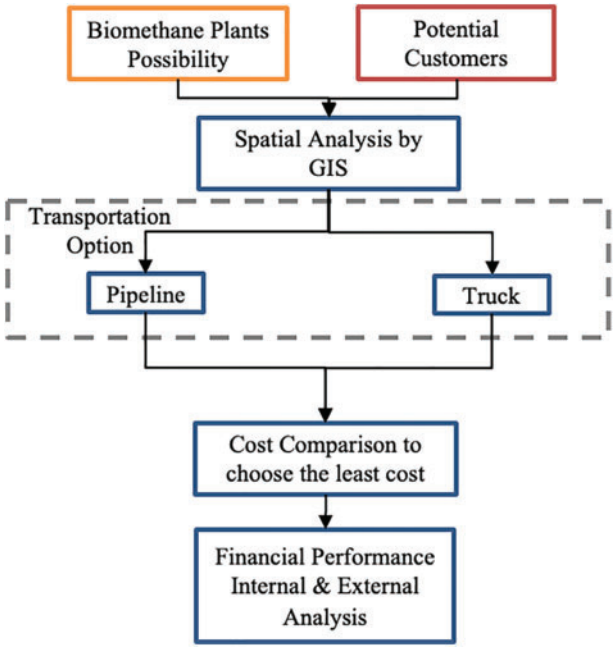

Fig. 2. Conceptual framework.

TABLE I: Potential Customers in Riau Province

Customer	Location	Business status	Type	Demand (m^3/day)
A	Pekanbaru	Operation	Mall	629
B	Pekanbaru	Planning	Food	16.78
C	Pekanbaru	Operation	Food	52.78
D	Kampar	Construction	Plastic	567.5
E	Siak	Planning	Others	10,000

transportation mode. Interviews will be conducted with Companies with experience in CNG transportation and gas pipelines to obtain cost profiles. The interview was carried out in a semi-structured interview type.

This research will further explore potential customers' willingness to use biomethane through questionnaires. The data type is qualitative and quantitative data from industrial and commercial customers, such as:

- Existing fuel type and consumption.
- Encouragement to use biomethane.
- Willingness to use biomethane at a premium price.
- The expectation of the biomethane uses.

By obtaining the transportation cost profile and customer's views about biomethane, further analysis is carried out:

- Finance Modeling (IRR and NPV) for the biomethane business from the mode of transportation with the lowest transportation profile.
- Sensitivity analysis of biomethane sales economies of scale.
- Business strategy to be implemented based on internal and external analysis.

3. Discussion

Based on survey data conducted by PT Perusahaan Gas Negara Tbk, five potential customers who needed natural gas were taken as a sample for this research. These customers are shown in Table I.

These potential customers have been surveyed electronically regarding their interest in biomethane. Based on the survey results, all potential customers were willing to use biomethane, but only one expressed interest in a renewable energy certificate, even buying at a premium price. In Fig. 3, the survey also showed that potential customers' main concerns were price and security of supply. The next was operational continuity and the safety aspect. The last is the environmental aspect:

3.1. Biomethane Plant Location

From the position of potential customers, a radius area of 65 km is created from each potential customer's position in the form of a blue circle (Fig. 4).

From the spatial analysis among the position of palm oil mills based on Ministry of Energy and Mineral Resources (2023) and the position of potential customers in Fig. 4, the palm oil mills that intersect all circles with a radius of 65 km from potential customers and fulfill biomethane demand, 11,265 Nm^3/day, are

1. PTPN V-Sei Buatan (PSB), Capacity 60 ton/jam FFB (10,320 Nm^3/day biomethane)
2. PTPN V-Lubuk Dalam (PLD), Capacity 30 ton/jam TBS (5,160 Nm^3/day biomethane)

After obtaining the location of the biomethane factory, the actual distance from the biomethane factory to potential customers can be summarized in Table II.

From Table II, the PSB source will be optimal as the primary supply source for potential customer E. Meanwhile, PLD will be optimal as the primary source of biomethane supply for other potential customers in Pekanbaru City.

3.2. Transportation Option Analysis

The Transportation option analysis assumes that filling station operations are carried out 24 hours/day and 360 days/year. An interview with CNG transportation and gas pipeline company resulted in a cost profile below:

3.2.1. Trucking

Based on Class II and Class III Road, Table III shows trucking transportation mode options referred to Raja Rafa Samudra (2023).

The choice of truck sizing for transportation determines the travel time and will be related to the amount of capital and operation expenditure costs. The assumed parameters used are as follows:

1. Compressed Biogas (CBG) filling time, parameter assumption:

- Preparation/dismantled/administration: 15 minutes.
- Dispenser flowrate: 550 Sm^3/hour.

2. CBG Round Trip Time:

- Truck speed is assumed to be 25 km/hour when loaded with CBG and 30 km/hour when empty.
- Breaks are taken every 3 hours, each for 15 minutes.

3. CBG Unloading time, parameter assumption:

- Preparation/dismantled/administration: 30 minutes.

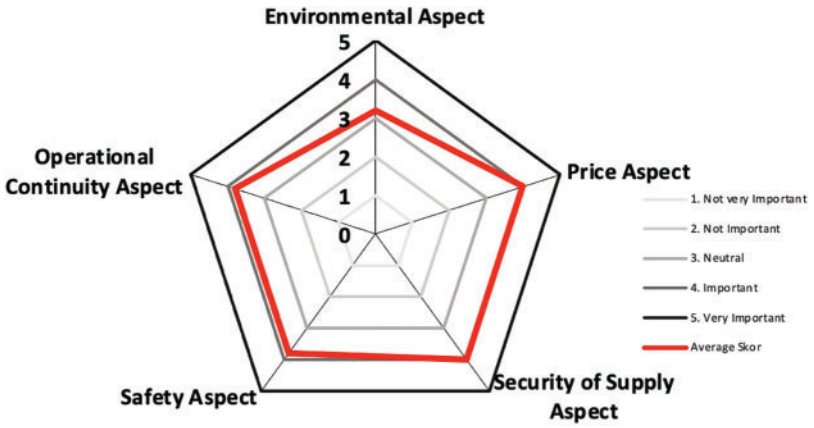

Fig. 3. Importance level of aspects in customers' view.

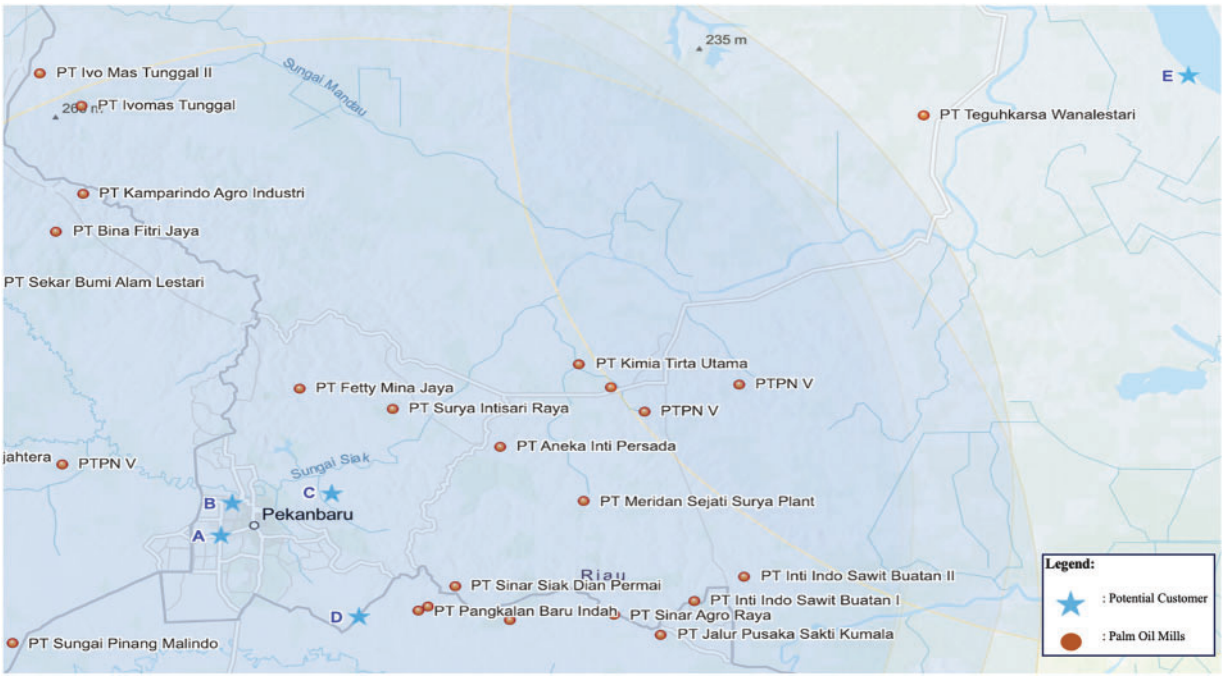

Fig. 4. Spatial analysis for biomethane plant location.

TABLE II: Distance Biomethane Plant-Potential Customer

Biomethane plant	Potential customer distance (km)				
	A	B	C	D	E
PSB	82	58	72	64	65
PLD	76	50	67	58	76

TABLE III: Trucking Transportation Mode Option

Parameters	Unit	20 ft truck	10 ft truck	Cascade skid	Skid arm-roll 36
Road category	Class	3	2	3	3
Cylinder type	–	IV	IV	I	I
Cylinder cap.	wlc	350	350	151	65
Cylinder no.	Units	24	55	27	36
Working pres.	Barg	250	250	250	250
CBG volume	Sm^3	2236	5124	1085	737.5

Note: wlc = water liter capacity.

TABLE IV: Travel Time, Truck Requirement, and Cost Profile to Customer E

Item	Unit	20 ft truck	10 ft truck	Cascade skid
Round travel time	Hour	6.02	6.02	6.02
Req. trip for supply	Trips/month	62	141	290
Truck provided	Unit	1	2	6
CMOS* provided:	Unit	3	5	6
Cost	IDR			
Capital exp.	Billion	19.4	15.85	5.26
Operation exp.	Million/month	137.84	177.32	295.66

Note: *CMOS = CNG Mobile Storage.

TABLE V: Travel Time, Truck Requirement, and Cost Profile to Potential Customers around Pekanbaru

Item	Unit	Customer			
		A	B	C	D
Round travel time	Hour	6.82	4.92	6.16	5.5
Req trip for supply	Trips/month	26	3	8	24
Truck provided	Units		1		
CMOS provided	Units	3	2	3	3
Cost	IDR				
Capex					
Truck	Million		575		
Skid	Billion	1.5	1	1.5	1.5
Opex					
Fuel	Million/month	8.48	1.51	2.30	5.97
Driver & Ass.	Million/month		16.03		
Trip allowance	Million/month	5.2	0.6	1.6	4.8
Regular maint.	Million/month	0.99	0.27	0.70	0.08
Tyre replace.	Million/month	0.91	0.07	0.25	0.64
Ins & Cert.	Million/month		1.51		

- Outlet pressure: 4 barg
- Discharge Time: Follow the customer's CBG consumption.

Based on the parameter assumptions above, the travel time, truck requirements, and cost profile required to transport CBG from the PSB Palm Oil Mill to Customer E are obtained as described in Table IV.

The other four potential customers in Pekanbaru are relatively small in biomethane demand. The assumptions used in calculating customers in Pekanbaru are:

- Customer E is an anchor buyer, and overhead cost calculations are charged to Customer E's transportation cost calculation.
- All potential customers in Pekanbaru will use a one-arm-roll truck.

With these assumptions, the transportation profile of the other four prospective customers in Pekanbaru-PLD is shown in Table V.

3.2.2. *Pipeline*

Based on Kaiser and McAllister (2023), calculating the diameter of the pipe to convey biomethane of 416.67 m^3/hour and a length of 65 km using the Waymouth formula obtained a pipe with a diameter of 4 inches.

Cost profile using references from PGN, and the profile is as follows:

1) Capex: Rp. 188.42 billion.
2) Operational expenditure:
   - O&M Cost: Rp. 7.85 million/month
   - Distribution Cost: Rp. 7.85 million/month
   - Overhead Cost: Rp. 7.85 million/month
   - Insurance Cost: Rp. 21 million/month

3.3. *Environment Analysis*

Environment Analysis includes internal and external factors by grouping them through SWOT (Strengths, Weaknesses, Opportunities, and Threats) Analysis. The following is a SWOT analysis of the implementation of biomethane at a Gas Distribution Company (GDC).

3.3.1. *Strength*

Several internal factors that are advantages of GDC are:

- Own massive natural gas infrastructure that can be utilized for biomethane.
- Experienced in trading natural gas, which has similar properties to biomethane.
- The gas trading permit can be used for biomethane trading.
- The existing sales organization can be utilized to do market development for biomethane.

3.3.2. *Weakness*

Several internal factors that are GDC's weaknesses are:

- There is no control over biomethane sources.
- Need to gain experience in handling gas supplies originating from renewable resources.

TABLE VI: Biomethane Price Profile PSB to Customer E (S/MMBTU)

Price component	20 ft truck	10 ft truck	Cascade skid	Pipeline mode
Biomethane*		8–10		
Compression*		1–2		
Transportation	2.87	2.76	2.43	25.55
PRS*		0.1–0.5		
Overall	11.97–15.37	11.76–15.26	11.53–14.93	34.65–38.05

Note: * = (Amartya & GIZ, 2022).

TABLE VII: Biomethane Price Profile PLD to Potential Customers Pekanbaru (S/MMBTU)

Price component	Three customers (A, C, and D)	Four customers (A, B, C, and D)
Biomethane*	8–10	
Compression*	1–2	
Transportation	6.69	7.70
PRS*	0.1–0.5	
Overall	15.79–19.19	16.80–20.20

Note: * = (Amartya & GIZ, 2022).

3.3.3. *Opportunity*

Several external factors that could become opportunities for the development of the Biomethane business at GDC are:

- By choosing the proper mode of transportation, the biomethane business requires less capital expenditure than natural gas.
- Government support for the development of biomethane considering that electricity demand has been oversupplied and biomethane from POME needs to be utilized to achieve the energy mix target of 23% in 2024.
- Encouragement of palm oil mills to reduce carbon emissions from POME treatment.

3.3.4. *Threat*

Several external factors that could pose a threat to the development of the Biomethane business at GDC are:

- In Pekanbaru, natural gas networks are available in several locations and can replace biomethane because natural gas prices are cheaper than biomethane.
- Palm Oil Mills companies can enter the biomethane business because there are no restrictions on biomethane trading players.
- Customers can easily switch to natural gas.
- The road infrastructure from the palm oil mill location to potential customers is in poor condition.
- Fluctuating production depending on the dynamics of palm oil production on climate aspects, world palm oil prices, and palm oil varieties.

3.4. *Risk Analysis*

The main risks for the use of biomethane in Pekanbaru can be identified as follows:

1) *Supply Shortage:* According to the survey results, biomethane supply security is the main risk of biomethane utilization projects. Reduction in biomethane supply can be caused by:

- Palm oil mills decrease the production or change technology, which reduces biomethane's feedstock, POME, or even stops.
- Biomethane yield is low due to the low quality of POME.

2) *Customers change their fuel from biomethane to natural gas:* Fuel change from a customer is one of the factors that influences the continuity of Biomethane sales. Based on the results of the survey, only one in five potential customers needs a renewable certificate. For this reason, natural gas is one of the factors that poses a risk to the continuity of biomethane sales because the price is cheaper than biomethane.

3) *Traffic accident on biomethane transportation:* Transportation from the Biomethane Plant to customer locations with a frequency of over 100 monthly trips can cause accidents. If an accident occurs, it will affect sales because the target frequency is significant.

4) *Biomethane explodes during operation or transportation:* Like Natural Gas, Biomethane is a flammable gas. By pressing up to 200 Barg when transported to customers, it has the potential to explode if not handled properly.

4. Findings and Results

4.1. *Transportation Mode*

Based on the interview results about the cost profile and the IRR target for the transportation cost component, which is 12%, the following is a comparison of the final price of biomethane among transportation modes. Table VI describes the biomethane price profile for Customer E from PSB. The table shows that the truck with the Cascade Skid Dedicated option has the lowest biomethane price.

The other four potential customers have a relatively small biomethane demand, and the locations are around Pekanbaru City, so the trucking mode will be gathered among the customers. The final price of biomethane was analyzed by combining four or three prospective customers, with Customer B not being served to prove that

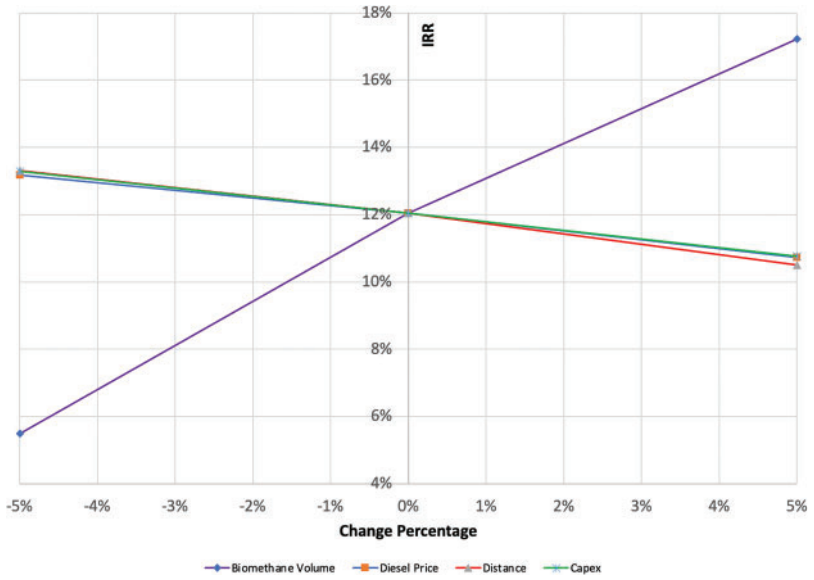

Fig. 5. Project sensitivity.

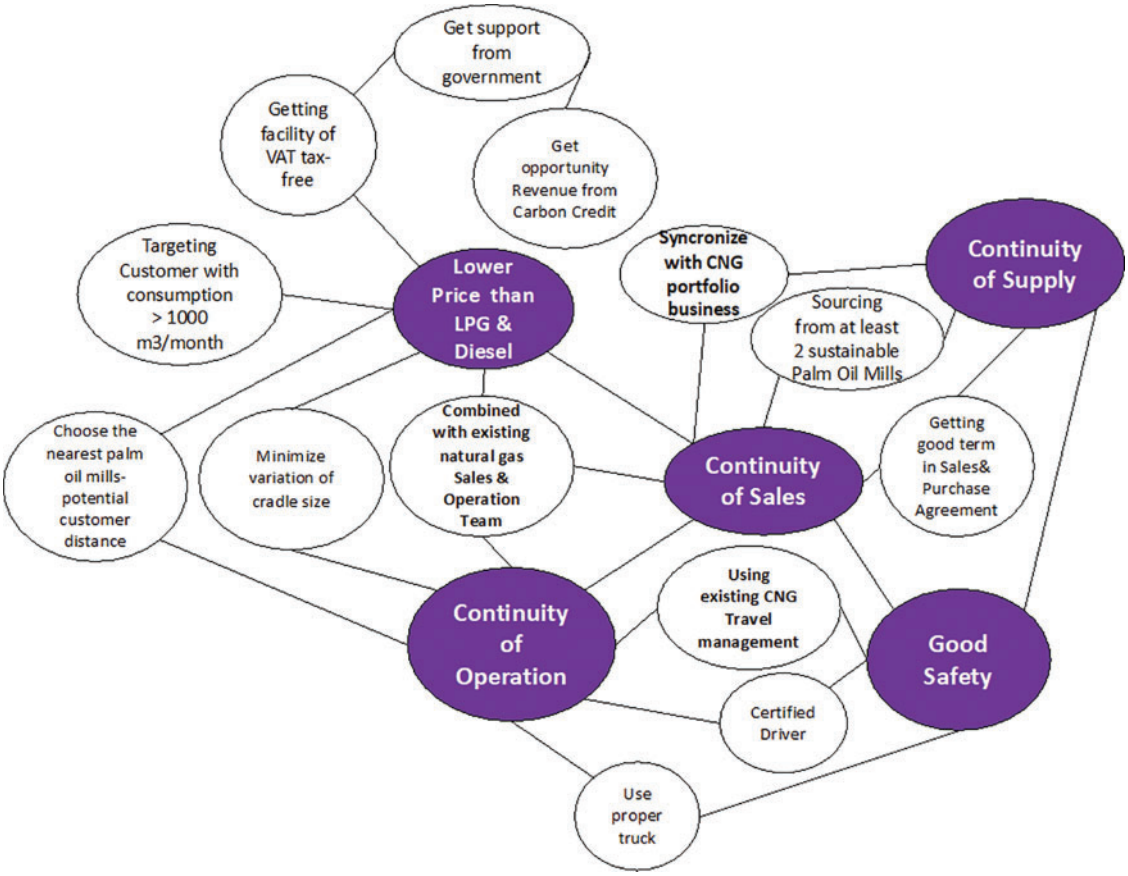

Fig. 6. Biomethane activity system.

the customer's demand below 1000 m^3/month is not economical. Table VII shows the comparison of the final biomethane price between clustering four or three potential customers in Pekanbaru City.

The cost profile above shows that if Customer 2 is included in the cluster of potential customers to be served, the aggregate transportation costs will slightly increase even further. For this reason, Customer 2 should be considered for service again.

4.2. Sensitivity Analysis

Sensitivity analysis was carried out on the following aspects:

- Biomethane volume
- Capex
- Distance
- Diesel Price

Fig. 5 shows that the most sensitive to the project's economics is the volume of biomethane that will be sold.

A 5% reduction in traded biomethane volume from the initial projection could cause the project IRR to decrease from 12% to 5.5%. For this reason, it is necessary to pay attention to reliability in terms of supply and sales.

4.3. Business Strategy

Based on the survey results, it is known that the important factors for potential customers in biomethane are price and supply security, followed by continuity of operations and safety aspects. In addition, considering that the most sensitive factor for project economics is the commercial volume of biomethane, it is necessary to maintain stability in the sales volume of biomethane.

Utilizing GDC's strengths is essential to get competitive prices while still paying attention to the aspects of security supply, continuity of operations, and safety aspects, such as:

- Utilize existing sales and operations team in Pekanbaru to support customer acquisition and service as well as service during operations.
- Existing CNG travel management and call center system.
- CNG business portfolio and existing infrastructure.
- Apart from utilizing existing strengths to gain competitive advantage, from the analysis that has been carried out, the activities that need to be carried out are:
- Selection of palm oil mill locations as biomethane production closest to potential customer locations.
- Target potential customers whose biomethane needs are above 1000 m^3/month.
- Obtain support from the government, including tax facilities, CNG transportation permits, and potential revenue from carbon credits.
- Minimize variations in cradle size to make transportation easier.
- Driver certification and using proper trucks to ensure safety during transportation to maintain operation continuity.
- Negotiation to obtain good terms in sales and purchase agreements.
- Collaborate with at least two sustainable palm oil mills to reduce dependency on one source and reduce the risk of fluctuations in biomethane production.

The relationship between these activities and the value proposition to potential customers can be described in Fig. 6.

5. Conclusion

Based on the study of five potential biomethane customers in Riau Province, Indonesia, the aspects that should be considered in offering biomethane to customers were price and supply security. Road condition, distance from customer to biomethane plant, and volume of customer's biomethane demand affect the selection of transport type. Based on spatial analysis and cost analysis, trucking is the most appropriate mode of transportation to serve potential customers in Riau. The CMOS size depends on the volume of customer's biomethane demand.

By selecting palm oil mills located within 76 km and trucking mode with the right type of CMOS, potential customers in Riau can be supplied with biomethane at a more affordable price than LPG or diesel oil while still maintaining project economics at an IRR level of 12%. One customer with a demand of 16.78 m^3/day biomethane should be reconsidered for service because it burdens the economy of other potential customers.

The most sensitive variable to the economics of biomethane utilization is the volume of biomethane that can be sold. Therefore, strategies to maintain stability or increase the sales volume of biomethane need to be considered in developing biomethane.

This research focuses on the study of biomethane transportation. Recommendations to obtain further feasibility of biomethane utilization should be carried out regarding:

- The interest of palm oil mill owners in biomethane development.
- Optimization of biomethane production costs in palm oil mills.
- Cradle size compatibility at customer location.
- Utilization of carbon credit potential to support the economics of biomethane utilization.

Conflict of Interest

The authors declare that they do not have any conflict of interest.

References

Amartya, Energy, & GIZ Explore (2022). Biomethane potential for industrial and commercial sector in Indonesia.

Badan Pusat Statistik Indonesia (2022). *Statistik Kelapa Sawit Indonesia 2021*. Catalog 5504003. https://www.bps.go.id/id/publication/2023/11/30/160f211bfc4f91e1b77974e1/statistik-kelapa-sawit-indonesia-2022.html.

BloombergNEF & WBCSD (2021). Hot spots for renewable heat decarbonizing low-to medium-temperature industrial heat across the G-20 (report). https://www.wbcsd.org/download/file/12957.

Gabungan Pengusaha Kelapa Sawit Indonesia, G. A. P. K. I. (2021). Palm oil performance in 2021 and prospect in 2022. https://gapki.id/en/news/21136/palm-oil-performance-in-2021-and-prospect-in-2022.

Gold, S., & Seuring, S. (2011). Supply chain and logistics issues of bio-energy production. *Journal of Cleaner Production*, *19*(2011), 32–42.

Udin, H., & Agus, H. (2018). Palm oil mill effluent recycling system for sustainable palm oil industries. *Asian Journal Environment Technology*, *2*(1), 52–62. http://repository.lppm.unila.ac.id/7137/1/Udin-journal.bioremediation-forum-Vol%202%20No.1-2018-pp%2052-62.pdf.

Iakovou, E. K., Vlachos, D., Toka, A., & Malamakis, A. (2010). Waste biomass-to-energy supply chain management: A critical synthesis. *Waste Management*, *30*(2010), 1860–1870.

Kaiser, M., & McAllister, E. (2023). *Pipeline Rules of Thumb*. Elsevier Inc.

Koonaphapdeelert, S., Aggarangsi, P., & Moran, J. (2020). *Biomethane Production & Applications*. Springer. https://doi.org/10.1007/978-981-13-8307-6.

Ministry of Energy and Mineral Resources (2023, Juli). *Potensi Limbah Industri Kelapa Sawit*. https://geoportal.esdm.go.id/potensiebtke/.

Raja Rafa Samudra, P. T. (2023, Juli). *CNG Equipment*. https://rajarafasamudra.com/?page_id=20.

Winrock International (2015). Buku Panduan Konversi POME Menjadi Biogas Pengembangan Proyek di Indonesia. https://winrock.org/wp-content/uploads/2016/05/CIRCLE-Handbook-INDO-compressed.pdf.