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Optimal Biomethane Injection into Natural Gas Grid – Biogas from Palm Oil Mill Effluent (POME) in Malaysia

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Abstract

The Malaysian government aims to facilitate the renewable energy (RE) sector by introducing the National Renewable Energy Policy and Action Plan during 2010. 4,000 MW of installed RE capacity is targeted by 2030, with 410 MW biogas capacity. Palm oil mill effluent (POME), agro-based industries and farming industries are identified as potential sources of biogas. It was studied that more than 500 kt of biomethane could be produced yearly if all the POME is treated anaerobically. The utilization of biomethane has remained unexplored for its injection into natural gas grid. This papers aims to identify the potential of POME biomethane injection into natural gas grid by using the BeWhere model, a techno-economic spatial explicit model. The locations, capacity and technology of biogas refinery plants will be identified based on cost minimization of the full supply chain of biogas production. The result shows that 135 - 227 biogas plants were selected, supplying 40% - 67 % residential fossil gas demand, under different carbon price implementation and fossil gas subsidy scenarios.

Keywords: biogas, biomethane injection, POME, renewable energy (RE), BeWhere

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1 Introduction

The National Renewable Energy Policy and Action Plan was established by the government of Malaysia during 2010 [1]. The policy aims to increase RE in power generation mix of the country, to facilitate RE industry development, to ensure RE generated at reasonable price, to ensure environmental sustainability for future generation and to improve awareness on the importance of RE [2]. To move towards that direction, Ministry of Energy, Green Technology and Water (KeTTHA), Malaysia sets a target of near to 4,000 MW of installed renewable energy capacity by 2030, accounting to 10 % of nation energy mix. The total installed capacity of RE has reached 3.5 % during 2013 [3].

The RE to be potentially explored includes biogas, biomass, municipal solid waste (MSW), small hydro and solar photovoltaic. For biogas potential, the maximum potential can be achieved from POME, agro-based industries and farming industries. A total capacity of 410 MW from biogas is targeted by 2028. It is assumed that the lifespan of the production plant is 25-30 years [2].

Since Feed-in-Tariff (FiT) for electricity generated from renewable source, for example biogas was introduced, biogas capturing and converting it into electricity is gaining popularity among the palm oil operators, despite reducing greenhouse gases emission. For example, Sungai Kerang Palm Oil Mill (211,475 m^3), Syarikat Cahaya Muda Perak (232,745 m^3) and United Plantations Berhad (226,641 m^3) [4]. However, the potential of upgraded biogas, biomethane injection into natural gas grid remains unexplored. This paper thus aims to identify the optimal planning for biomethane injection into natural gas grid.

Nomenclature

RE	renewable energy
POME	palm oil mill effluent
KeTTHA	Ministry of Energy, Green Technology and Water of Malaysia
MW	megawatt
GWh	gigawatt hour
MSW	municipal solid waste
FiT	feed-in-tariff
GHG	greenhouse gases
FFB	fresh fruit bunch
mmBtu	one million British thermal unit

2. Methodology

The model adopted in this study is the BeWhere model, a geographic explicit techno economic model [5-7] which find the optimal location of new bioenergy plants by minimizing the costs and the emissions of the entire supply chain. In this study, the model has been implemented with the biogas technology having palm oil mill effluent (POME) produced in Peninsular Malaysia, as potential feedstock. The goal is to identify the optimal locations of biogas refineries plants as well as the corresponding biomethane injection infrastructures. The biogas supply chain is presented in Figure 1. The scope of this study focus on palm oil mill effluent (POME) as feedstock and injection of biomethane into natural gas grid as biogas utilization. After being collected, the feedstock is transported from the palm oil mills to the biogas plants through truck or train. Biogas (50 – 62.5 % CH_4) generated from anaerobic digestion of POME is then upgraded to biomethane (90 - 97% CH_4) by adopting a specific upgrading technology, which capacity is endogenously determined in the optimization procedure. The obtained biomethane (101kPa) is then compressed to meet the gas pressure of natural gas grid (240 – 345 kPa) prior to injection.

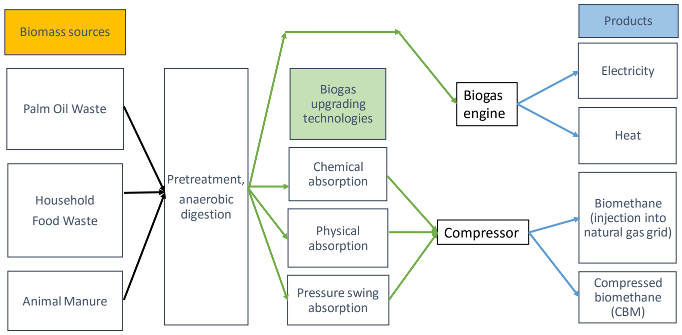


Figure 1. Biogas supply chain

2.1 Feedstock availability

In 2010, there were around 400 palm oil mills in Malaysia, generating about 71.5 million m^3 POME. The data is provided by SIRIM Berhad. It is assumed that palm oil mills operate for 12 hours per day, 300 days per year. It is also assumed that 1 m^3 of POME is generated from 1 tonne of fresh fruit bunch [8]. The red points in Figure 2 (top left) shows the locations of the palm oil mills in Peninsular Malaysia. There are a total of 209 palm oil mills in Peninsular Malaysia with a total generation of 36 million m^3 POME yearly.

2.2 Biorefineries technologies

Different technology for biogas upgrading are commercially avaiable in the market, in this case study we have focused on the most commonly adopted, being physical absorption, chemical absorption and pressure swing absorption. Prior to upgrading, POME is treated anaerobically, where the cost of construction is included. For each technologies, three different capacities have been considered [9]. Their technical features and cost are summarised in Table 1.

Table 1. Summry of biogas refinery technologies [9]

Biogas refineries technology	**Efficiency median (%)**	**Capacity (m^3/h)**	**CAPX cost (kEUR/(m3/h))**	**O&M cost (EUR/(m3/h))**
Physical absorption	92.8	100	9.5	13.8
		250	5	10.2
		500	3.5	9.0
Chemical absorption	93.1	100	9.5	14.4
		250	5	12
		500	3.5	11.2
Pressure swing absorption	89.2	100	10.4	12.8
		250	5.4	10.1
		500	3.7	9.2

2.3 Natural gas demand and the district gas gates

The natural gas consumption is obtained from the Energy Commission of Malaysia. During year 2010, there were around 1 million mmBtu natural gas consumed [10]. The consumption of natural gas in each city is derived from the residence and commercial consumption weighted by the population in each cities during 2010. The purple points in Figure 2 (top right) shows the natural gas demand; meanwhile the blue points in Figure 2 (bottom left) shows the district gas gates, in which it can potentially be the injection point of biomethane. Such injection points are connected to the selected biogas plants through specific stainless steel gas pipelines, having a unit investment cost of 227.64 MYR/km/y for a diameter size of less than 16 inches [15].

2.4 Transportation network

The road network and rail network in Peninsular Malaysia is obtained from the Digital Chart of the World [16]. The blue lines in Figure 3 (bottom right) represent the road network while the red lines represent the railway network. The data is available in the form of shape file. The Geographic Coordinate System used is GCS_WGS_1984. A GIS-based transport network model is created to perform a network analysis with the origin-to-destination distance matrices. The feedstock can either be distributed by truck or train, or combination of both. In a similar way the pipeline network is considered, and extension of the pipeline can be assessed whenever needed and if economically viable.

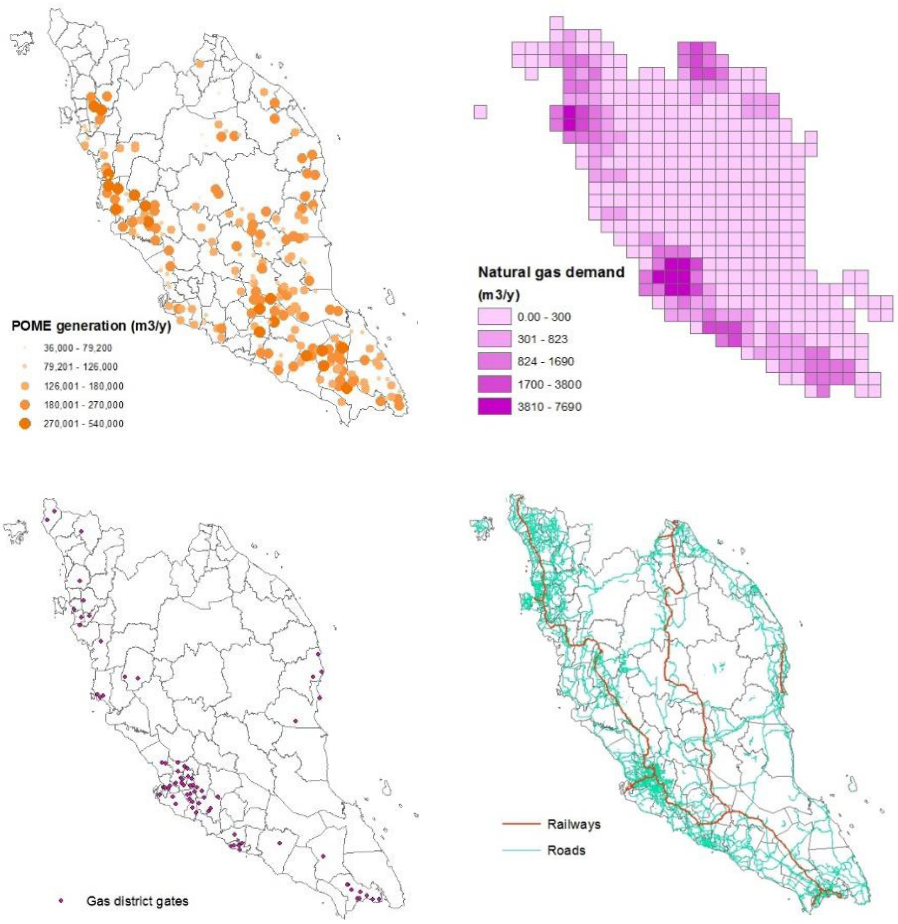


Figure 2. (Top left) POME production in Peninsular Malaysia [11]. (Top right) Natural gas demand [12]. (Bottom left) Natural gas district gates in Peninsular Malaysia [10]. (Bottom right) Road and railway network in Peninsular Malaysia [16].

A series of scenarios are carried out with varying capital cost and also some policy factors such as carbon emission cost, fossil gas subsidy reduction.

3. Results and discussion

The market price of fossil gas is around 13.45 MMYR/PJ during 2010 [13]. Such value has been adopted in the baseline scenario while the carbon price has been set at a reference value of 80 MYR/tCO_2. Under these assumptions, the model selects 227 biogas upgrading plants giving a total biogas production of 2.08 PJ/y, with selected POME being transported by truck. Physical absorption represents the preferred upgrading technology for the selected plants, mainly due to its relatively lower investment cost and O & M cost. In terms of carbon emissions mitigation, the proposed biogas production lead to a total of 2.4 MtCO_2 emissions, representing a 67 % emission reduction compared full fossil gas scenario.

3.1 Biogas production sensitivity to carbon emission price and fossil gas subsidy reduction

Carbon emission prices ranged from 60 to 100 MYR/tCO_2 are studied. Figure 3 (left) shows that beginning at 70 - 80 MYR/tCO_2, 135 - 227 biogas plants are constructed with a total biomethane production of 33 – 56 Mm^3/y, which is 40 – 67 % of residential gas demand. Increasing carbon price lead to a higher biomethane production, which reaches is maximum values (83 Mm^3/y) at a corresponding carbon price of 90 MYR/tCO_2, biomethane production reaches its maximum production of.

Malaysia government provides ample subsidies for all fuels, which included natural gas. The subsidy is amounted to nearly 40 % of fossil gas market price [14]. The model thus considered different percentage of fossil gas subsidy between the range of 20 – 60 % at baseline scenario. Figure 3 (right) informs by lowering fossil gas subsidy from 40 % to 30 %, biomethane production is increased to its maximum production, 83 Mm^3/y. Note that it is under circumstance of 80 MYR/tCO_2 carbon price implementation.

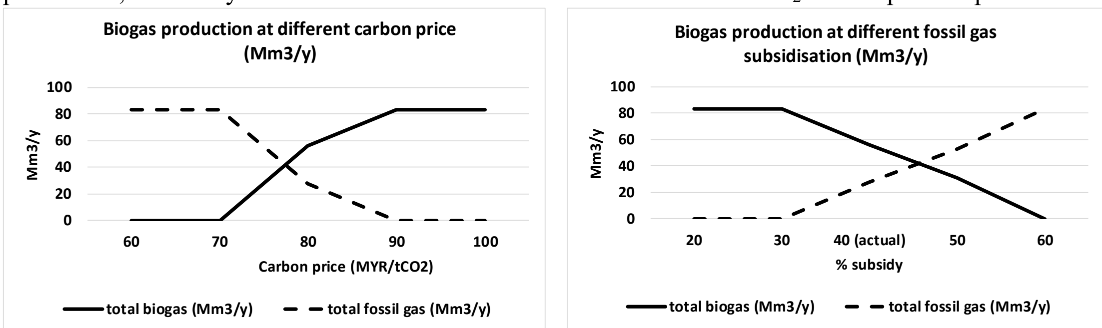
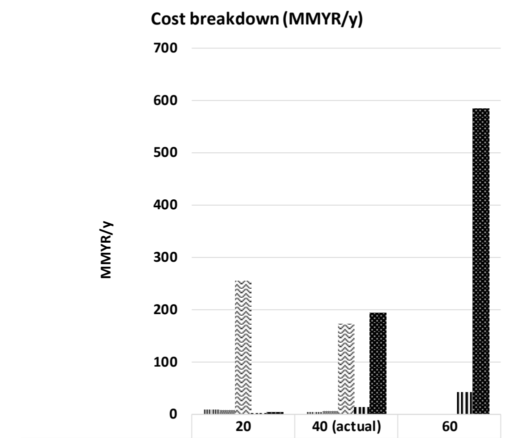


Figure 3 Biogas production at different carbon emission price (left) Biogas production at different fossil gas subsidy (right)

3.2 Cost breakdown

Gas pipeline investment cost, amounted to around 231,000 MMYR/y, consisted near to 100 % of the total cost of biogas upgrading plants. One of the reasons is due to the limited number of gas stations available for injection, in the case of baseline scenario, 227 biogas plants are selected while there are only 41 injection stations.

In order to study how carbon price is affecting the production of biomethane, cost breakdown is analysed without pipeline cost. Figure 4 (left) shows the cost breakdown of biogas plant construction at 20 %, 40 % (actual) and 60 % fossil gas subsidy. It is observed that carbon emission cost consists more than 50 % in the total cost of biogas production at 40 % and 60 % fossil gas subsidy. The result shows that implementing carbon price can effectively promote biomethane utilisation for its significant economic influence. It is in alignment to Malaysian government promotion of renewable energy by reducing 10 Mt CO_2 emission by 2030.



	20	40 (actual)	60
biomass transport cost	7.55	3.01	0.00
O & M cost	7.19	4.84	0.00
plant investment cost	255.11	171.84	0.00
fossil gas cost	0.03	13.59	41.57
carbon emission cost	3.97	193.13	584.58

% subsidy

Figure 4. Cost breakdown at different fossil gas subsidy.

Conclusion

The result shows that 135 - 227 biogas upgrading plants are selected, supplying 40% - 67% residential fossil gas demand when carbon price of 70 - 80 MYR/tCO_2 is implemented. Reducing fossil gas subsidy. Pressure swing absorption (PSA) is selected to upgrade biogas to biomethane at the capacity of 500 m^3/h biomethane production. this study shows that different potential approaches might support the adoption of biomethane injection into natural gas grid as a competitive energy option. One of them is to have biogas injection stations located in proximity of the biogas units. The construction of biomethane injection infrastructure, especially the construction of gas pipelines should be incentivised, besides subsidy reduction of fossil gas and implementation of carbon price on its emission. The model can also be further developed to evaluate the economic impact of incentivising biomethane injection infrastructure. Various biomass sources that is nearer to the biomethane injection stations should also be evaluated spatially and economically.

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Biography

Dr. Haslenda Hashim is Associate Professor at the Universiti Teknologi Malaysia (UTM). She received her PhD from the University of Waterloo, Canada. She specializes in process planning, scheduling, modeling, simulation and optimization. She is a certified trainer for the ASEAN Energy Management Schemes, technical expert for the green technology fund scheme, expert panel advisor for the Malaysia Green Technology Corporation Malaysia and the Iskandar Regional Development Authority (IRDA).

Poh Ying Hoo is a second-year PhD student from the Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia. Her research interest is on biogas supply chain planning and optimization. Her current thesis project is about spatial-economic optimization of biogas utilization in Malaysia and to propose policy tools in promoting biogas utilization in the country.