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# Economic Feasibility of Feed-in Tariff (FiT) for Biomethane Injection into Natural Gas Distribution Grid

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Feed-in Tariff (FiT) is a policy mechanism designed to promote investment in renewable energy technologies. Despite the successful implementation of FiT mechanism for renewable electricity generation in Malaysia since 2011, FiT for renewable gas, biomethane injection into the natural gas grid remains unexplored. This study aims to identify the financial feasibility of biomethane injection into natural gas grid by proposing FiT rate. Net Present Value (NPV) approach is used to calculate the FiT rate for the first five years of biomethane injection into natural gas distribution grid (NGDG), under 8 % degression rate. Preliminary results identified that FiT rate of 40.81 to 227.85 MYR/GJ for biomethane production plants within 1,000 m from the injection point at 4 different sizes: 250 $m^3$/h, 500 $m^3$/h, 750 $m^3$/h and 1,000 $m^3$/h. Biggest plant size (1,000 $m^3$/h) shows lowest FiT rate (40.81 MYR/GJ), although the FiT rate is almost double the piped gas price, 28.85 MYR/GJ. Judging from the trend of increasing piped gas price, along with government subsidy rationalisation plan, it is foreseen that biomethane, under proper policy regulations and FiT mechanism, can be a competitive renewable gas as natural gas. Recommendations are discussed and provided for successful implementation of biomethane injection into the grid.

## 1. Introduction

Biomethane is a renewable gas obtained from cleaned and upgraded biogas. Unlike biogas, it has higher methane composition which is suitable to be used as fuel for vehicles or even injection into the natural gas grid as one of the sources of energy supply (Eker and Daalen, 2015). Biomethane is more commonly used in the Europe as it reduces their reliance on imported natural gas. It is reported that there was a total of 357 biomethane plants by the end of 2014, where 12 % of biomethane produced was utilised as vehicle fuel (Cucchiella and D'Adamo, 2016).
There are many reasons that cause the uncertainty of biomethane production, for example, the availability of resources, capacity of biomethane plant, financial feasibility, demand of renewable gas and competition from renewable electricity production from biogas (Eker and Daalen, 2015). Electricity generation from biogas is commonly incentivised and supported by various policy instrument like FiT mechanisms or quotas which makes it commercially attractive to renewable energy developers. However, the same mechanism is rarely applied to support biomethane injection into the grid (Budzianowski and Budzianowska, 2015) despite it carries abundant benefits that complement the weakness of other renewable sources. The intermittent nature of wind and solar energy makes energy supply and demand matching a challenge (Barton and Infield, 2004), where the energy produced can't be stored. In addressing the challenge, energy systems nowadays are becoming more integrated (Franco and Salza, 2011). Biomethane and some other gases play an important role in optimising the integration by enabling energy conversion (Clegg and Mancarella, 2016), for instance, biomethane storage. Biomethane bridges the gap of temporal and geographical gaps between energy supply and demand. Biomethane can also be adopted in centralised and decentralised energy systems (Lee et al., 2017), and even large-scale energy storage applications. In comparison to utilisation of biogas for power and heat production through combined heat and power (CHP) unit, upgrading of biogas to biomethane is more environmental friendly as it has lower greenhouse gas (GHG) emission (Cucchiella and D'Adamo, 2016).

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However, biomethane injection into the grid also possess shortcomings, for example, its high capital cost. It will not be an attractive investment options without the support of policy instruments. Thus, thus paper aims to propose the FiT mechanism and study the financial feasibility of biomethane injection into natural gas grid under the proposed FiT rate.

## 2. Gas consumption in Malaysia: non-power sector

Figure 1 illustrates the natural gas consumption by sectors (residential, commercial, industrial) in Peninsular Malaysia during 2010 to 2015, and forecasted natural gas consumption from 2016 to 2020. During 2015, 166,403,660 GJ of natural gas was supplied to the industrial users, that is more than 99.34 % of total piped gas supplied (Energy Commission, 2016). The average growth rate of piped gas consumption from 2010 to 2015 was 6.77 %.

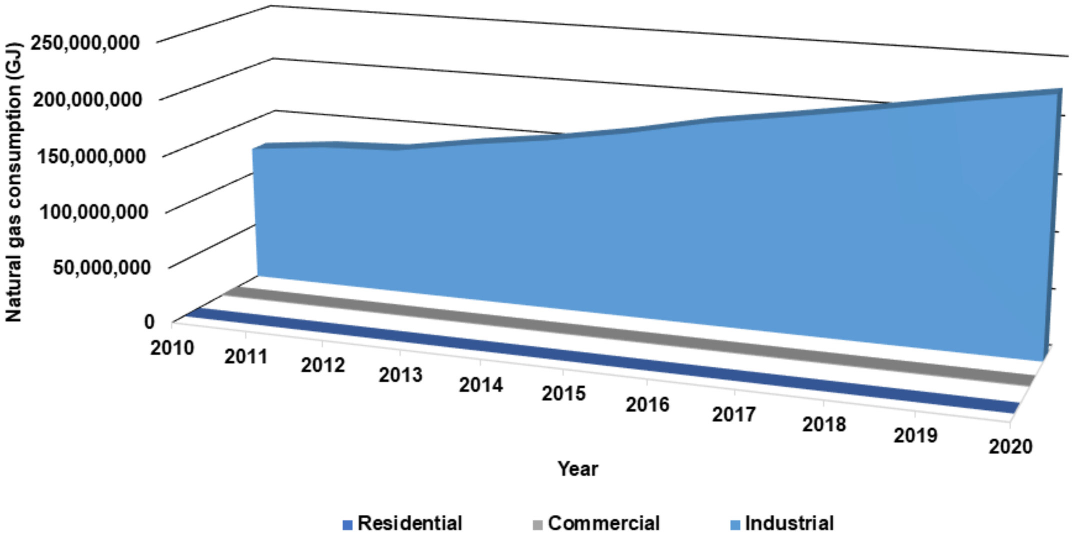


*Figure 1: Natural gas consumption by sector in Peninsular Malaysia during 2015 (Energy Commission, 2016)*

Figure 2 illustrates the breakdown of piped natural gas sales volume by industry. It is observed that rubber products industry and food, beverage and tobacco industry are the two main consumers of natural gas where both industries total up to a 59 % of gas sale volume. During 2015, Gas Malaysia Berhad (GMB) delivers gas to 796 industrial users, 862 commercial users and 12,571 residential users (Energy Commission, 2016). The number is forecasted to grow with GMB's increasing expansion of NGDS infrastructure.

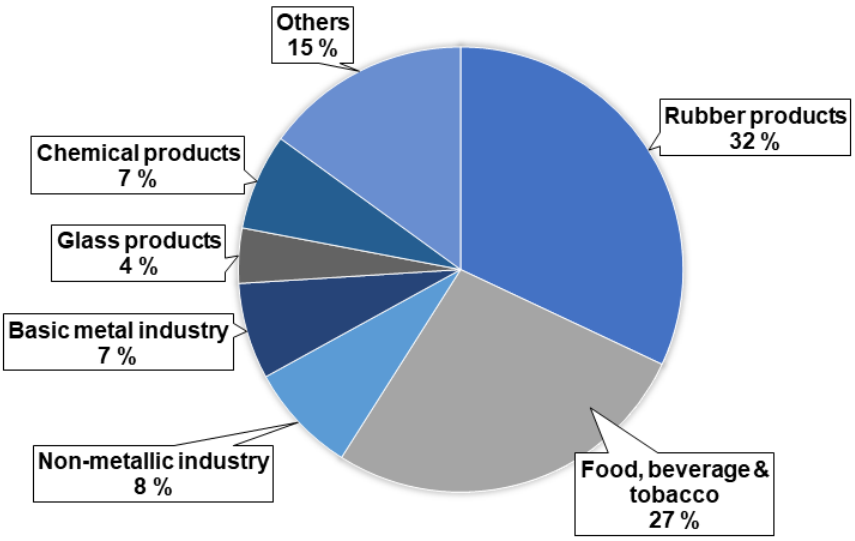


*Figure 2: Sales volume breakdown of Gas Malaysia based on industry during 2015 (Energy Commission, 2016)*

## 3. Potential biomethane production in Malaysia

The 6 biomass wastes that can potentially be used as feedstock of anaerobic digester (AD) for biomethane production in Malaysia come from Palm Oil Mill Effluent (POME), sewage treatment plant, chicken manure, swine manure, dairy cattle manure and municipal food waste. These six biomass wastes are identified based on their high production, high Chemical-Oxygen Demand (COD) or high $CH_4$ conversion rate. COD is an important indicator of biogas production during anaerobic digestion process of liquid waste. It is assumed that for every kg of COD digested, 0.35 kg $CH_4$ is produced (Harikishan, 2009).

POME is a waste water produced during the process of crude palm oil production. POME has very high Chemical-Oxygen Demand (COD), as high as 51,000 mg/L as compared to other industrial waste water (MPOB, 2014). Sewage treatment plant produced sludge which has a COD content of 430 mg/L (Metcalf and Eddy, 2003). For solid waste, the $CH_4$ conversion rate are ranged between 0.032 – 0.55 $m^3$/kg solid digested. Based on a review conducted by Kumaran et al. (2016), a summary of potential biomethane production from biomass wastes in Malaysia during 2014 is compiled in Table 1.

*Table 1: Estimated $CH_4$ production from six main feedstocks of AD in Malaysia (Kumaran et al., 2016)*

| Feedstocks | Amount | COD (mg/L) | $CH_4$ produced ($m^3$/d) | Energy produced (TJ/y) | Installed capacity of gas engine (MW) |
|---|---|---|---|---|---|
| POME | 58.53 $Mm^3$/y | 51,000 | 1,044,760,500 | 12,776 | 553.31 |
| Sewage treatment plant | 2,748.45 $Mm^3$/y | 430 | 1,132,513 | 5,643 | 197.92 |
| Chicken manure | 77,209 t/d | NA | 3,860,458 | 19,414 | 674.24 |
| Swine manure | 14,720 t/d | NA | 552,000 | 2752.2 | 96.47 |
| Dairy cattle manure | 30,400 t/d | NA | 632,320 | 3151.5 | 110.48 |
| Food waste | 908.33 t/d | NA | 355,950 | 1772.1 | 61.87 |

A rough calculation shows that the total energy that can potentially be produced from biomass waste is 45,508.6 TJ/y, which is equivalent to 31.2 % of natural gas energy consumption in Malaysia. The biomethane produced could have been delivered to users, be it residential, commercial or industrial users by injection into the natural gas grid.

## 4. Feed-in Tariff (FiT) calculation

There are many different types of FiT designs, for example, FiT design with purchase obligation, FiT design with stepped tariff, FiT design with tariff degression, FiT design with premium option, FiT design with equal burden sharing and FiT design with forecast obligation. It is also important to determine the tariff level and duration of support. Tariff level can be designed by identifying the biomethane generation costs. In this study, only investment cost and operational cost are included during tariffs calculation, other cost like licensing expenses are not included here. Eq(1) shows the calculation of total cost of biomethane generation.

$$Total\ cost = Cap_{UP} + OM_{UP} + Cap_{COM} + OM_{COM} + Cap_{PIPE} + OM_{PIPE} \quad (1)$$

Where:

| | | |
|---|---|---|
| $Total\ cost$ | = | Total cost of biomethane production (MYR/y) |
| $Cap_{UP}$ | = | Capital cost of upgrader (MYR/y) |
| $OM_{UP}$ | = | Operational and maintenance cost of upgrader (MYR/y) |
| $Cap_{COM}$ | = | Capital cost of compressor (MYR/y) |
| $OM_{COM}$ | = | Operational and maintenance cost of compressor (MYR/y) |
| $Cap_{PIPE}$ | = | Capital cost of pipeline (203.2 mm diameter) (MYR/y) |
| $OM_{PIPE}$ | = | Operational and maintenance cost of pipeline (203.2 mm diameter) (MYR/y) |

Table 2 shows the information regarding the CAPEX and OPEX of biomethane production for the production of 1,000 $m^3$/h biomethane plant (Hoo et al., 2018).

Net Present Value (NPV) is used to calculate the FiT rate based on the total cost of biomethane generation, as shown in Eq(2) (Lim et al, 2015).

$$NPV = \frac{\sum_0^n\left(\frac{Production\times FiT}{year} - \frac{OPEX}{year}\right)}{(1+r)t} - CAPEX \quad (2)$$

where:

| | | |
|---|---|---|
| $NPV$ | = | Net Present Value |
| $Production$ | = | Biomethane production of plant (GJ) |
| $OPEX$ | = | Total operational and maintenance cost (MYR/y) |
| $FiT$ | = | Feed-in Tariff (MYR/GJ) |
| $r$ | = | internal rate of return (%) |
| $t$ | = | anticipated project lifetime (y) |
| $CAPEX$ | = | Total capital cost (MYR/y) |

NPV is assumed at zero, which indicates all cash inflows and outflows reach at breakeven point, it is also the minimum earning without causing losses to the investors. $Production$ is taken at 1,000 $m^3$/h biomethane production, with 0.03866 GJ/$m^3$ energy content. $r$ is taken at 10 % while the project lifetime is projected for 20 y.

*Table 2: Information of biomethane production at different pipeline length*

| Pipe length, L (km) | $Cap_{UP}$ (MYR/y) | $OM_{UP}$ (MYR/y) | $Cap_{COM}$ (MYR/y) | $OM_{COM}$ (MYR/y) | $Cap_{PIPE}$ (MYR/y) | $OM_{PIPE}$ (MYR/y) | Cost per production (MYR/GJ) |
|---|---|---|---|---|---|---|---|
| 1 | 108,000 | 2,880 | 46,550 | 342.53 | 13,170 | 658.51 | 4.41 |
| 2 | 108,000 | 2,880 | 46,550 | 342.53 | 26,341 | 1,317.01 | 4.77 |
| 3 | 108,000 | 2,880 | 46,550 | 342.53 | 39,510 | 1,975.52 | 5.12 |
| 4 | 108,000 | 2,880 | 46,550 | 342.53 | 52,681 | 2,634.03 | 5.48 |
| 5 | 108,000 | 2,880 | 46,660 | 342.53 | 65,851 | 3,292.54 | 5.83 |

## 5. Result and Discussion

FiT is estimated based on 4 different biomethane production sizes: Production 1, Production 2, Production 3, Production 4. Table 3 shows the information for each production sizes.

*Table 3: Biomethane production sizes*

| Production | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Production ($m^3$/h) | 1,000 | 750 | 500 | 250 |
| Production (GJ/y) | 309,310 | 231,982 | 154,655 | 77,328 |

Results show that the proposed FiT ranged from 40.81 to 227.85 MYR/GJ for the first 5 y, among which Production 1 (1,000 $m^3$/h) has the lowest estimated FiT while Production 4 (250 $m^3$/h) has the highest estimated FiT (Table 4). As renewable energy technologies are expected to build and grow in volume in the future, which resulting in cheaper implementation cost, thus degression is a mechanism introduced to compensate for future cost reductions. A low 8 % degression rate is assumed in this study to ensure biomethane injection into the gas grid remained financially attractive to renewable energy developers (Lim et al., 2015).

*Table 4: Proposed FiT rate based on 4 biomethane production sizes (MYR/GJ)*

| Production | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1$^{st}$ year | 56.96 | 75.95 | 113.93 | 227.85 |
| 2$^{nd}$ year | 52.41 | 69.87 | 104.81 | 209.62 |
| 3$^{rd}$ year | 48.21 | 64.28 | 96.43 | 192.85 |
| 4$^{th}$ year | 44.36 | 59.14 | 88.71 | 177.42 |
| 5$^{th}$ year | 40.81 | 54.41 | 81.62 | 163.23 |

To further analyse the situation, a graph is plot as shown in Figure 3. It is then compared to the gas tariff in Peninsular Malaysia from 2015 to 2018 (Figure 4), with projection to 2019 (GMB, 2017). Under the national subsidy rationalisation plan, subsidised piped gas price is adjusted two times annually until it reaches parity with liquefied natural gas (LNG), which is in line with the Incentive Based Regulation (IBR) framework. Under IBR, gas price will be adjusted through Gas Cost Pass Through (GCPT) mechanism every six months starting from 2017.

It is observed that the proposed FiT for biomethane production at 1,000 $m^3$/h (Production 1) is almost double the average piped gas tariff in Peninsular Malaysia. Taking the average of piped gas tariff from 2017 to 2019, that is 28.85 MYR/GJ, the ratio of proposed FiT to piped gas tariff decreases from 1.97 to 1.41 during the first five years. Judging from the trend, it is foreseen that in future the ratio could go down to 1, indicating biomethane price can be as competitive as natural gas price under specific biomethane plant distance from the grid. It is also found that biomethane injection could be an attractive business option under the proposed FiT as the cost per production of biomethane is 4.41 to 5.83 MYR/GJ for 1 to 5 km pipe length. Further analysis is needed at increasing pipeline length as construction of pipeline facility made up the biggest portion of biomethane injection capital cost (Hoo et al., 2018).

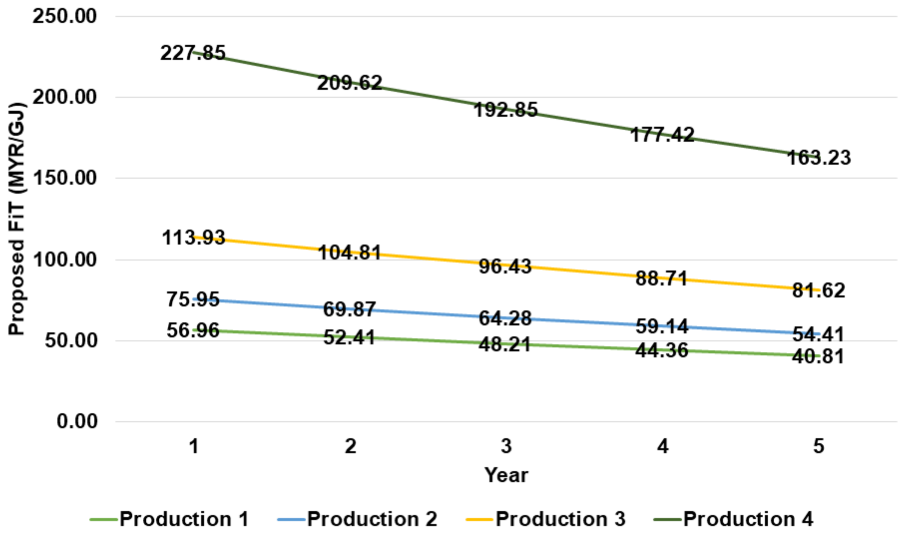


*Figure 3: Proposed FiT for biomethane injection during the first 5 y at 8 % degression rate*

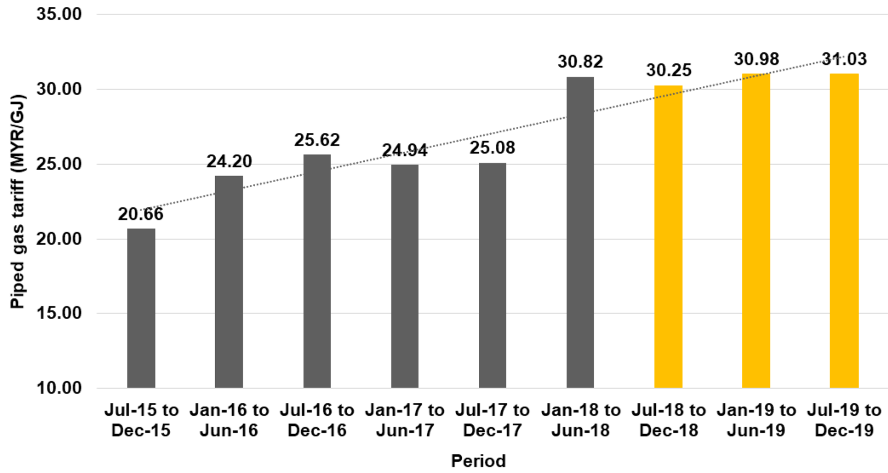


*Figure 4: Average piped gas tariff for non-power sector in Peninsular Malaysia (GMB, 2017)*

It is recommended that further validation to be carried out for the proposed FiT by comparing the rate to biomethane FiT of other countries in relative to natural gas price, as natural gas price in Malaysia is still relatively cheaper than other countries. Similar to how the electricity FiT was implemented along with collection of 1 % (2011) then 1.6 % (2014) surcharge from the power consumers (SEDA, 2014), a viable surcharge should be imposed on users from non-power sector in order to make the FiT mechanism work. Distance of plant feasibility from the grid should also be identified, learning from previous lesson where electricity connection to grid are only financially feasible for those generation within a specific distance from the grid.

## 6. Conclusions

Since the implementation of FiT mechanism for renewable electricity feed in to the grid in 2011, electricity generation from biogas has gained more attention from its operators. Due to limited quota for electricity feed in and location constraint, not every biogas produced are utilised. Further exploration is needed to tap into other possible utilisations. One of them is through upgrading of biogas to biomethane, where biomethane can then be injected into the grid. This study used the NPV approach to estimate the FiT rate. It is found that under the proposed FiT (40.81 – 227.85 MYR/GJ), it is financial feasible for biomethane to be injected into the grid. Although the price of biomethane FiT is almost double the piped gas price, with government subsidy rationalisation plan which resulting in higher piped natural gas price, it is foreseen biomethane can be a competitive renewable gas as natural gas. Policy formulation and incentives based on production plant sizes are needed to ensure the successful implementation of biomethane injection into grid.

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