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Successful Biogas Implementation – A Mini-review on Biogas Utilization, Energy Policies and Economic Incentives

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Biogas is considered as a renewable energy resource and its demand is increasing due to environmental concern and energy security. However, in some countries where they rely heavily on the non-renewable fossil fuels as energy source, government subsidies and dropping oil prices have made biogas a less favourable option to the market. This paper reviews successful biogas implementation as a source of energy with effective government policy support. It is concluded that integrated planning and effective policy enforcement among the government departments are the major factor to the success. The government departments included those that have direct influence on the supply and demand chain of biogas. For example, the energy department, transport department, agricultural department, waste management department, science and technology department and finance department. Economic incentives are one of the policy tools that is frequently used. Besides, strategic collaborations and strong network between the like-minded countries is also the driving factor to the success.

1. Introduction

The improving uptake of renewable energy all around the world has given hope to the climate issue which hundreds of countries in the world have been combating. During 2015 Paris Climate Conference – COP 21 that was held in Paris early December 2015, there was a study that revealed that the global carbon emission has reach a stall despite the growing of economics.

195 countries also agreed to maintain the global average temperature increment to below 2 ºC above pre-industrial level with the elimination of fossil fuels subsidies in 20 major countries (Sutter, 2015). It shows that renewable energy plays a very important role in combating climate change.

There are many different renewable energy investment options that were adopted in different countries, considering its environmental, economic, technical and social impact. For instance, wind energy, solar energy, biomass energy, hydropower and geothermal energy. Biomass, which has long been used as a source of energy, produces compost as end product, biogas occasionally if biomass is digested anaerobically. Biogas can be used to replace non-renewable fossil fuels for different purposes. For instance, fuel for engines, fuel for turbines for electricity generation, fuel for vehicles and fuel for boilers or cooking purpose.

Over the past years, studies have been carried out to improve the technology of biogas upgrading. In Europe, the upgrading technology and implementation plan of biogas has a very strong supportive network. Biogas could be upgraded to that of natural gas standard so that it could be fed into the natural gas grid.

Review has also been done to compare biogas upgrading technologies and its utilization. There is lack of study on how a country's policy would affect the progress of biomass energy, especially biogas to be used as one of the source of renewable energy.

In this review paper, reviews of how policy and its instrument in each country affect the development of biogas industry is discussed (Figure 1). The utilisations of biogas will be described in relation to countries policy. A conclusion is drawn based on the comparison and relations.

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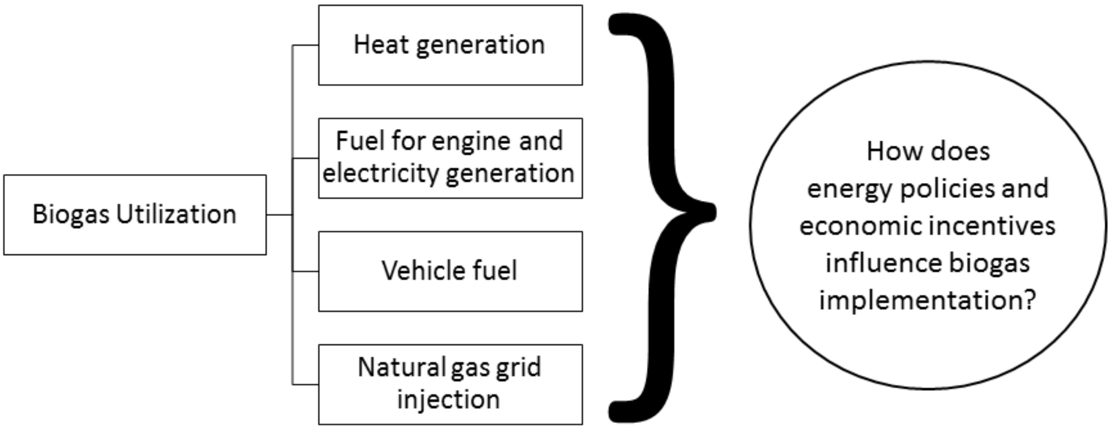

Figure 1: Overview of the review

2. Review of biomethane utilization

The major factors influencing biogas adoption are the socio-economic of a country, government policies on energy, environment and technological reform as summarised in Table 1. In developed countries with more advance technology biogas as transportation fuel and industrial usage (heat and electricity) are more favourable. In developing country, biogas technology is more widely used as fuel for heating at household level such as in Bangladesh (Khan et al., 2014).

2.1 Heat generation

Biogas can be used as fuel for stoves or boilers, however, it has to fulfil the standard of safety regulations to ensure the safety of user. Natural gas is usually compressed to 20 mbarg when supplied in domestic stoves. Higher heating value is obtained when natural gas is compressed. Biogas has to be upgraded to higher methane concentration for it to be compatible with natural gas heating value. The concentration of H_2S must be kept at very low level (below 10 ppm), as H_2S is toxic and corrosive (Sun et al., 2015).

Usually boilers are equipped with desulphurization unit and is does not require another separate unit to remove H_2S. Biogas can be used as fuel without upgrading. However, if the boiler were to be used as combined heat and power plants (CHPs), H_2S must be reduced to below 250 ppm. This is because presence of H_2S would corrode boilers and affect the function of lubricating oil (Weiland, 2010).

Chemical absorption is the most suitable biogas upgrading technology for biogas in domestic stoves usage. This is because of its high requirement for CH_4 purity and its energy efficiency. If CH_4 concentrated can be tolerated at a lower concentration, one may consider water scrubbing, physical absorption, pressure swing absorption and membrane technology, which these technologies have less costly operating and maintenance (O&M) cost. There are also chemical and biological means to desulphurise biogas.

2.2 Fuel for engine and electricity generation

Biogas can be used to produce electricity through combustion in gas turbine engine. There is no specific requirement of methane concentration. However, there is a need for modification in the combustion for low methane concentration. There is also another way to improve the efficiency by increasing the methane concentration (Sun et al., 2015). The choosing of technology to upgrade biomethane have to consider the trade-offs between cost and overall efficiency.

H_2S concentration should be limited to below 200 – 1,000 ppm. It depends on the size of the turbine. For low cost removal of H_2S, biological method can be considered. Siloxanes, which can be found in biogas, has a potential of corroding the turbines blades and nozzles. This is because of its potential of depositing silica compounds. These silica compounds have high potential to cause erosion too.

Eventually, turbine fails to function (EPRI, 2006). Besides, water content should be controlled to prevent condensation of fuel gas (Sun et al., 2015).

Table 1: Biogas utilization & policy enforcement based on countries' socioeconomics

Category	Biogas utilization	Countries	Purpose	Project/Program/Policy	Reference
Least developed countries	Heat Generation, Cooking Services	Bangladesh	Environmental benefits (63 % average frequency) and economic (59 % average frequency) benefits.	National Domestic Biogas and Manure Program (NDBMP)	(Kabir et al., 2013)
Developing countries	Heat Generation, Cooking Services	China	Energy saving.	Biogas digesters at Lianshui and Guichi China	(Wang et al., 2007)
	Heat Generation, Cooking Services	India	Government's policy to deliver renewable energy services to households across the countries.	National Biogas and Manure Management Program	(Raha et al., 2014)
	Fuel for Engine and Electricity Generation	Malaysia	Policy target to increase renewable energy share to 11 % by 2020.	Fifth Fuel Policy 2000 National Renewable Energy Policy 2010 Small Renewable Energy Power (SREP) Programme Renewable energy incentives Feed-in-Tariff (FiT)	(Hashim and Ho, 2011)
	Fuel for electricity generation	Thailand	To achieve 14 % of all energy needs from renewable resources by 2022.	Energy Conservation Promotion Act Renewable Energy Development Plan	(Aggarangsi et al., 2013)
Developed countries	Natural Gas Grid Injection	European countries	Contribution on reducing greenhouse gases (GHG) emission; policy target to increase renewable energy share to 20 % by individual country members.	Intelligent Energy for Europe (IEE)	(Sabine and Ankit, 2013)
	Vehicle fuel	Sweden	To impose profound societal structural change in combating climate change.	Swedish Transport Policy	(Fallde and Eklund, 2015)
	Food waste management	Japan	To reduce greenhouse gases emission.	Future Energy Policy Feed-in Tariff Scheme for Renewable Energy	(Matsuda et al., 2012)

2.3 Vehicle fuel

Using biogas as fuel for transport has been highly promoted worldwide, especially in Sweden (Larsson et al., 2015). Besides using biogas to fuel cars, trucks and heavy goods vehicles (HGVs), biogas is also used to run train (Fallde and Eklund, 2015). For biogas to be injected into vehicles, a relatively high purity of CH_4 is needed, as compared to the standard required by injection into natural gas grid. The suitable technologies that can be used to upgrade biogas to biomethane included cryogenic separation and chemical absorption. Cryogenic separation is best to be used for liquid fuel. At the same time, iron hydroxide/oxide and impregnated activated carbon are suitable candidates for H_2S removal (Sun et al., 2015).
Swedish government has been promoting the usage of biogas as transportation fuel. About 5% of biogas produced in Sweden is used for transportation mean. The number of gas-driven vehicles in the country has doubled to over 50,000 vehicles from 2011 to 2015. For example, private cars, buses, trucks and Heavy Goods Vehicles (HGVs). These transportation tools are equipped with gas tanks. Besides that, over 200 gas filling stations has been expanded. These filling station also stocks gas for HGVs (Union, 2015).
Successful implementation of renewable energy in a country can never run away from effective policy. Firstly, biogas industry in Sweden is highly boost by their government's progressive environment policies at state and local authority level. Secondly, government also introduced subsidies and tax breaks, for example, big reduction in preferential tax, environmental awards, free parking and waiving of road tolls. Thirdly, government also set high environmental standard for procurement for goods and services. Fourth, there is strong collaboration for biogas future development strategy between Swedish Energy Agency, Swedish Board of Agricultural and Swedish Environmental Protection Agency (Larsson et al., 2015).

2.4 Natural gas grid injection

The quality of biomethane must be upgraded if it was to be injected into the natural gas grid. The standard of biomethane should meet the natural gas standard that is transported using the natural gas grid. The European Standard for gas quality is as shown in the Table 2 (Sun et al., 2015). Different limitation of CH_4 caused the variety in technology used. If a higher concentration of CH_4 is required, the technologies that are more appropriate to be used are pressure swing absorption (PSA) or chemical absorption. PSA and membrane technology have the advantage of removing O_2 and N_2 together with CO_2. The method of iron hydroxide/oxide and impregnated activated carbon can also be used to meet the quality requirement (Sun et al., 2015).

Table 2: Standards of gas quality for European countries (Sun et al., 2015)

Parameters	Value
Min. CH_4 (% mol)	70 – 98
Max. CO_2 (% mol)	1 – 8
Max. O_2 (% mol)	0.01 – 1
Max. N_2 (% mol)	2 - 10
Max. H_2 (% mol)	0.1
Max H_2S	2 – 15 mg/m^3
Max. total sulphur	10 -150 mg/m^3
Water dew point Water content	-5 ºC/8.4 mPa – 0ºC/0.4 mPa (-5 ºC/max operating pressure) – 1 g/m^3

From the discussion of the four-main biogas utilization, it tells that different ways of biogas utilization needs to meet different standard. Table 3 illustrates the summary of standard requirement for all biogas utilization methods: heat generation, engine and electricity generation, natural gas grid injection and vehicle fuel.
The development of biomethane projects still rely closely to support scheme. This is the current market price of biomethane is still much higher than natural gas price, making it very hard to compete with natural gas. Despite supporting the biogas projects with government policy and regulations, the government has been putting in effort to boost the biomethane industry with financial support. For example, Feed-in Tariff (FiT) for gas and electricity generated from renewable source (Wojciech et al., 2015), provision of biofuel quota and certificate system, applying beneficial tax policy and investment aid for biomethane production plants. Boosting of biomethane production eventually created job opportunities to thousands of engineering and plant operators in the continent (Sabine and Ankit, 2013).

Table 3: Summary of standard requirement for all biogas utilization methods

Biogas Utilization	Pressure	Min heating value/ power	Min CH_4	Max H_2S	Upgrading technologies	Remarks	Reference
Heat Generation (Fuel for stoves/boilers)	100 mbar[a]	NA	93 %[a]	10 ppm[a]	Water scrubbing, physical absorption, pressure swing absorption, membrane technology[a]	Boiler combustion has high tolerance towards biogas quality[b]	([a]Sun et al., 2015) ([b]Weiland, 2010)
Fuel for Engine and Electricity Generation	NA	12 MJ/m^3	30 %	200 – 1,000 ppm	Biological desulphurisation	The higher the CH_4 concentration, the higher the engine efficiency.	(Sun et al., 2015)
Natural Gas Grid Injection (EU)	50 bar	NA	70 - 98 %	2 - 15 mg/m^3	Chemical absorption, pressure swing absorption	Upgrading technologies depends on CH_4 purity requirement. / pressure varies at intake.	(Sun et al., 2015)
Vehicle Fuel	200 bar (compressed biogas) / liquefied biogas	34.81 MJ	97 %	NA	Chemical absorption, cryogenic separation	1 L petrol = 4 L compressed biogas = 1.7 L liquefied biogas	(Larsson et al., 2015)

*NA – Not applicable

3. Conclusions

The successful implementation of biogas in the developed countries, be it in heat and electricity generation or transportation fuel, shows highly integrated planning and policy, rules and regulations enforcement among the government sectors. It is especially shown in the departments that have high influence on the biogas supply and demand chain. It illustrates the government strategic planning and policy enforcement play a very crucial role to increase biogas share in the market. Strategic planning and resilient investment allow the provision of economic incentive to support the biogas industry, despite the competitive energy alternative in the country. The successful implementation of upgraded biogas injection into the natural gas grid in the European countries, under the lead of Germany demonstrate that strong collaboration between countries also plays a crucial role to increase biogas share in the energy sector. Besides policy enforcement, there is standardized upgraded biogas injection guideline for the plant operators. It then generates millions of job opportunities to the engineers. Countries with their strategic geographic location could potentially collaborate in order to develop biogas industry. The collaboration can help promoting green industry in the region, while securing energy supply.

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