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Development of a National Standard for a Biogas Grid in Thailand

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***Abstract*— The biogas industry in Thailand has undergone rapid growth in recent years. From having just 15 agricultural biogas plants in 1995, Thailand now has well over 2500 plants, with an annual production of 36 million m^3 of biogas. Excess biogas can be combusted and sold as electricity to the electric grid, sold in cylinders or used in Natural Gas Vehicles (NGV). A further usage is to pipe the biogas directly into customer's homes where it may be used for heating or cooking. In order to do this safely, a standard needs to be developed and implemented for the construction of a small scale biogas grid pipeline. Although international standards exist for Natural Gas transportation via pipeline, a standard specific for biogas has not been developed.**

The paper will outline the methodology used to develop this biogas grid standard. This standard should ensure that the grid is constructed and operated safely. The requirements would be different that those of a Natural Gas Pipeline since it is smaller in size and scope and strictly adhering to a large scale Natural Gas pipeline would be unnecessarily cumbersome and expensive.

The first part of this paper will list key features of the developed standard. In particular, the main differences between the biogas and natural gas pipeline will be emphasized. The final draft of the proposed standard will be submitted in August 2016 to the Thai Ministry of Energy by the Energy Research and Development Institute (ERDI) which has been given responsibility for the drafting of the biogas standard.

This second part will assess how big the potential is for biogas grids in Thailand. This includes an estimate of how much biogas could be delivered to customers via a biogas grid and the economic factors that govern its potential.

Keywords*— *Biogas grid; Standard Development; Pipeline safety;

I. INTRODUCTION

There is no internationally agreed upon definition for a biogas grid so the following shall be taken as a suitable definition for the time being. "A biogas grid is a network for the distribution of locally produced biogas/biomethane to end users in a local town or city to meet demand for a cleaner more efficient environmentally friendly energy source".

In Thailand there are many local biogas producers using animal waste as the raw material [1]. Most of this gas gets used on site in internal combustion engines that generate electricity. It was noticed in early 2015 that some biogas producers began transporting raw biogas directly to dwellings in their community for use in heating and cooking. Quality and safety standards were minimal and therefore the Thai ministry of energy decided that it was necessary to develop a standard for construction and operation of a biogas grid before numerous local grids were constructed in this manner. An easy solution would have been to translate in Thai a preexisting international standard however no such standard exists at the present time of writing.

There are several ASME, ISO and other international standards that are very relevant to a drafting new biogas grid standard, see Table II. Probably the most relevant standard is from the American Society of Mechanical Engineers, standard B31.8 – Transportation of natural and other gas by pipeline [2]. However this standard deals with large scale industrial size natural gas transportation which implementing on a local scale would be impractical or overkill.

It was decided to form a committee of 14 members to help draft the first version of a Thailand biogas grid standard. The committee consisted of experts from industry, academia and government. The committee met three times over the spring of 2016 and their recommendations lead to the first draft of the standard. The final version will be presented to the ministry of Energy in the fall of 2016. The committee members are shown in Table I.

TABLE I. STANDARD COMMITTEE MEMBERS

Company or Ministry	Type of Business	Number of Representatives
PTT	Industrial	2
Chualakorn University	Academic	1
Mahidol University	Academic	2
Ministry of Energy	Government	1
Scan Inter	Industrial	2
Chiang Mai University	Academic	2

Company or Ministry	Type of Business	Number of Representatives
Energy Research and Development Institute	Industrial	1
Pollution Control Department	Government	1
Energy Policy and Planning Office	Government	2

II. BACKGROUND

There are many standards that exist for gas pipelines and operations associated with them. It is intended for this paper to adapt existing standards for use in biogas grids in Thailand. A summary of some of the standards that could be directly or indirectly used in this work are shown in Table II.

TABLE II. APPLICABLE EXISTING STANDARDS

Standards	Criteria					
	Biogas quality	***Perso-nell***	***Materials***	***Welding***	***Test***	***O&M***
ASME B31.8 [2]			✓	✓	✓	✓
49 CFR Part 192 {US} [3]		✓	✓	✓	✓	✓
Gas Supply Code CAP 116A {SG} [4]			✓	✓	✓	✓
GSMR 1996 {UK} [5]	✓					✓
ISO 3183:2012 [6]			✓			
ISO 13847:2013 [7]				✓		
ASME B31Q [8]		✓				
UNI/TR 11537:2014 (Italy) [9]	✓					
ISO 13686:2013 [10]	✓					
ASTM A252 {US} [11]				✓		

The most commonly used standard in this field is the American Society of Mechanical Engineers standard B31.8 [2]. ASME standards are accepted for use in more than 100 countries around the world. This is partly because they are developed in a committee setting to ensure balanced participation and open access to public interest groups. ASME uses a consensus process. This provides confidence that if a recommendation is made based on ASME B31.8 it has been rigorously analyzed and agreed upon by subject matter experts.

III. METHODOLOGY

There were several areas involved in this standard development where an obvious answer was not available and a discussion about the optimal solution entailed. This section will summarize some of these issues and their outcomes.

The first thing the committee insisted on were limits on what this standard did not cover. It was agreed that no other gases shall be transported except biogas or biomethane. And this draft would only apply to the external use of biogas and its transport across public lands. It is not applicable when the gas is used only for private purposes.

Biogas Purity: At a minimum, it was agreed that the biogas should be set to a sufficiently high purity level to so that it can be safely combusted at the customer's location and not be excessively expensive to produce. Corrosive gases such as H_2S need to be removed before inserting into the biogas grid.

Research into other countries policies were carried out. In most countries the purity of the biogas is set to a level where it can be injected into the national gas grid. Table III shows the standards for biomethane across seven European countries. As can be seen, all have a minimum Methane content above 85%.

TABLE III. MINIMUM METHANE CONTENT IN BIOMETHANE FOR SELECTED EUROPEAN COUNTRIES ***[12]***

Country	Percentage of Methane Allowed % (Vol/mol)
Austria	96
France	86
Belgium	85
Czech R.	95
Holland	85
Sweeden	97
Switzerland	96

Holland has one of the lowest standards for biomethane purity levels since its natural gas grid is designed around the low calorific value of their offshore Groningan gas field [13]. The standard of biomethane allowed in the Netherlands is regulated by Gas Act of the Netherlands for local gas grids. Table IV shows certain specifications for the gas inside the Dutch gas grid.

TABLE IV. SELECTED CHARACTERISTICS OF NATURAL GAS AND BIOGAS IN THE NETHERLANDS ***[14]***

Component	Fraction Allowed
CH_4	≥ 85% (vol/mol)
CO_2	≤ 6% (vol/mol)
O_2	≤ 5% (vol/mol)
H_2	≤ 12% (vol/mol)
CO	≤ 1% (vol/mol)
Ammonia H_2O	≤ 3 (mg/Nm^3)

H_2S	≤ 5 (mg/Nm^3)
Odorant	≥ 10, 18-40 mg THT/m^3
Siloxanes	≤ 5ppm
Total Sulphur	≤ 45 (mg/Nm^3)

Evidence from the literature would suggest that a minimum level of methane in the biogas should be set around 85%. The higher the content of methane would mean more processing of the raw biogas at more expense [15]. Some suggested a low setting, such as 60% methane. After all it is just going to be used locally primarily for cooking. There were two strong arguments against this path.

The first is that gases with widely different Wobbe indices cannot be used in the same heating equipment [16]. For example a natural gas cooker or heater designed for a gas with a WI of 50 MJ/m^3 could not be used with a gas having a WI of 22.1 MJ/m^3 which is biogas with 60% Methane. So any equipment that combusts 60% biogas needs to be specially modified to burn this fuel, usually by enlarging the fuel nozzle [17]. This poses a safety risk for customers if they connect natural gas burners to the biogas outlet. The gas will flow out but not ignite causing a serious safety issue.

The exact range of Wobbe Index with accommodates a stable and safe combustion limit is largely dependent on the application and equipment. To be completely certain a gas can be used it is necessary to test the gas with the appliance. The European Association for the Streamlining of Energy Exchange (EASEE) has proposed a higher Wobbe Index range from 48.96 – 56.92 MJ/m^3 [18]. This corresponds to a gas relative density between 0.55 – 0.7 which is the range of densities for biogas as the methane content varies from 100% to 85%. The range is quite broad and some engine manufacturers have raised concerns that this range may not be ideally suited to their engines [19].

The second argument revolves around the heating value of the biogas. A low heating value means more time needed to heat the end product. Some experiments carried out at the Energy Research and Development Institute suggests the time to boil water is three time longer for 60% biomethane than 85%. This may dissatisfy the end users. Processing the biogas into a gas containing at least 85% methane would eliminate the above two issues and also be of sufficient quality for use as a natural gas substitute in vehicles [20]. Since 85% is also the proposed minimum Biomethane content for NGV's in Thailand [21]. These issues are presented in Table V below.

TABLE V. BIOGAS PROPERTIES AT DIFFERENT PURITY LEVELS

Quality	**Properties**	
	Wobbe Index	***Lower Heating Value***
Biomethane 85%	36.4 MJ/m^3	30.4 MJ/m^3
Biomethane 60%	22.1 MJ/m^3	21.5 MJ/m^3

Maximum Allowable Pressure: The maximum allowable pressure was another issue where a clear answer was not straightforward. If copper was to be used as a pipe material then the maximum pressure would be limited to 400 kPa, for plastic piping this pressure would be 689 kPa. Setting the maximum pressure to 400 kPa would allow any pipe material to be used from steel to plastics. Leak testing during installation could be done with gases instead of the more expensive hydrostatic testing if 400 kPa was set as the maximum and customer's premises would not require backup regulators.

An issue raised was the transport distance possible at this relatively low pressure. To investigate this, Mueller's Equation (High-pressure pipe for polyethylene) was used.

$$Q = \frac{2826 D_I^{2.725}}{S_g^{0.425}} \left[\frac{P_1^2 - P_2^2}{L}\right]^{0.575} \qquad (1)$$

Where
- Q = Flow, standard CFH
- S_g = Gas specific gravity,
- P_1 = Inlet pressure, lb/in^2 absolute
- P_2 = Outlet pressure, lb/in^2 absolute
- L = Length, ft
- D_I = Pipe inside diameter, in

This equation is plotted in Fig. 1 below. On average, the rate at which an average household uses biogas is 0.375 Nm^3 / hr. Therefore, if the pipeline is 10km long and 1 inch diameter it could supply 44 average houses. For a 1km long, 4 inch pipeline, 4746 average households are possible. Since these numbers were deemed sufficient for a local biogas grid it was decided that a maximum pressure of 400 kPa would be selected for this standard.

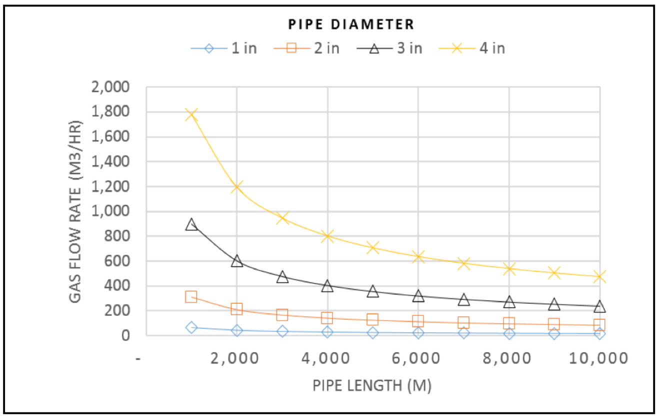

Fig. 1 Flow rate versus pipe length for different pipe diameters

Maximum Hoop Stress: The maximum allowable hoop stress in the grid was chosen to be 20% or less of the pipe minimum yield strength. Similar to the maximum pressure this criterion erred on the side of safety. Allowing this level of stress reduced the requirements elsewhere in the grid construction.

There was a) No need for special certification for welders who construct the grid b) No need for fracture toughness testing c) Simplifies the pipeline inspection process d) The pipe surface requirements become more manageable, there is no need to worry about minor notches or scratches e) Wider variety of joints permitted and f) There would be an easier installation requirement.

Odorization of gases: A gas in the biogas pipeline must be odorized so that at a concentration in air of one-fifth of the lower explosive limit, the gas is readily detectable by a person with a normal sense of smell. The odorant may not cause harm to people, materials or pipe. This requirement came from the International Organization for Standardization, number ISO 13734 [22]. The products of combustion from the odorant may not be toxic when breathed nor may they be corrosive or harmful to materials to which the products of combustion will be exposed. The biogas producer should carry out periodic ‘‘sniff’’ tests at the ends of the system to confirm that the gas contains odorant.

Design formula for steel pipe: The maximum diameter for steel pipe is determined in accordance with the following formula: The pressure is the actual maximum pressure allowed in the pipeline which is 400kPa.

$$D_{max} = 2\left(\frac{S.t}{P}\right) xFxExT \quad (2)$$

Where:

a) D_{max} = Nominal outside maximum diameter of the pipe in millimeters
b) P = Design pressure in kPa gauge, 400kPa
c) S = Yield strength of the pipe material in kPa
d) t = Nominal wall thickness of the pipe in millimeters
e) F = Design factor determined from Table VI
f) E = Longitudinal joint factor which is normally 1.0, except in rare cases
g) T = Temperature derating factor as shown in Table VII

Class Locations: The concept of class location comes from the ASME standard. This classifies the pipeline location into four different classes based on the risk to the general population. A ‘‘class location unit’’ is an area that extends 200 meters on either side of the centerline of any continuous 1.6 kilometer length of pipeline. Each separate apartment or room in a multiple apartment building is counted as a separate dwelling for this measurement.

(a) A Class 1 location is: Any class location unit that has 10 or fewer dwellings intended for human occupancy.

(b) A Class 2 location is any class location unit that has more than 10 but fewer than 46 dwellings intended for human occupancy.

(c) A Class 3 location is any class location unit that has 46 or more dwellings intended for human occupancy;

(d) A Class 4 location is any class location unit where dwellings with four or more stories above ground are prevalent.

TABLE VI. DESIGN FACTORS AND BURIAL DEPTH FOR DIFFERENT CLASS LOCATIONS

Class Location	Properties	
	Design Factor (F)	***Burial Depth below Surface***
1	0.72	800 mm
2	0.6	1000 mm
3	0.5	1000 mm
4	0.4	1000 mm

TABLE VII. TEMPERATURE DERATING FACTOR (T) FOR STEEL PIPE

Temperature Derating Factor	
Gas Temperature	***Temperature Derating Factor (T)***
120 °C or less	1.00
150 °C	0.967
175 °C	0.933
205 °C	0.90
230 °C	0.867

Similarities to ASME B.31.8: It was agreed that several sections of ASME B31.8 could be useful and used also in this standard. These are sections concerning the materials used, testing requirements and construction methods. A brief summary is given here but if further details are required they can be found in [2].

a) *Materials*: All pipe materials that are qualified for use are the same as ASME B.31.8. It is the responsibility of the biogas grid constructor to investigate the specific pipe, tubing or fitting to be used. The constructor should also determine material serviceability for the conditions anticipated. The selected material shall be adequately resistant to the liquids and chemical atmospheres that may be encountered.

b) *Components*: Each component in the pipeline, such as valves, fittings, regulators must be able to withstand the operating pressures and other anticipated loadings without damage or impairment of its serviceability. The compatibility may be based upon a pressure rating established by the manufacturer.

c) *Flexibility*: Each pipeline must be designed with enough flexibility to prevent thermal expansion or contraction from causing excessive stresses in the pipe or components, excessive bending or unusual loads at joints, or undesirable forces or moments at points of connection to equipment, or at anchorage or guide points.

d) *Underground Clearance*: Each underground pipeline must be installed with at least 305 millimeters of clearance from any other underground structure not associated with the pipeline.

e) *Testing*: All of the pipeline, except for plastic pipes, must be tested to at least 620 kPa gage. For plastic pipe the test pressure can be 150 percent of the maximum operating pressure. All joints must also be leak tested at these pressures. The pipe should be laid down in its trench with accessibility to all joints that pose a potential leak threat. The test procedure is as follows:

I. Pressurize the system slowly to 80% of the test pressure
II. Check for initial leaks with a bubble leakage test
III. Pressurize to the final test pressure and allow the system to stabilize for 15 minutes
IV. Monitor the pressure for at least 2 hours. There should be no noticeable pressure drop

f) *Above ground pipeline*: Each above ground pipe in the biogas grid, must be protected from accidental damage by traffic or other similar causes, either by being placed at a safe distance from the traffic or by installing barricades.

g) *Record Keeping*: Each operator shall make, and retain for the useful life of the pipeline, a record of each test performed under this standard.

h) *Emergencies*: Each operator shall prepare a manual of written procedures for conducting operations and maintenance activities and for emergency response. This manual must be reviewed and updated by the operator at least once each year.

i) *Leakage Survey*: Each operator shall conduct periodic leakage surveys. The exact type and scope of the leakage control program must be determined by the nature of the operations and the local conditions.

j) *Meter Installation*: Each meter and service regulator, whether inside or outside a building, must be installed in a readily accessible location and be protected from corrosion and other damage. Each service regulator installed within a building must be located as near as practical to the point of the line entrance. Each meter installed within a building must be located in a ventilated place and not less than a meter from any source of ignition or heat. Service regulator vents and relief vents must terminate outdoors. Each regulator that might release gas in its operation must be vented to the outside atmosphere.

k) *Deactivation*: Each pipeline abandoned or deactivated must be disconnected from all sources and supplies of gas and purged of gas. The valve that is closed to prevent the flow of gas to the customer must be locked to prevent the opening of the valve by persons other than those authorized by the operator.

IV. SUMMARY OF BIOGAS GRID STANDARD

At the time of writing the final draft has not yet been submitted to the ministry of energy. However, some of the basics recommendations, that will be included in the final draft, are summarized below:

1) The composition of the biogas shall depend on the end usage of the biogas. Domestic or Industrial.
2) For both cases the biogas CH_4 content shall be at least 85%. The contents of the remaining 15% are shown in Table VIII below.
3) The pressure in the biogas grid shall not exceed 400 kPa. For such a small grid size a large pressure is not required. This also simplifies a lot of the installation and testing procedures.
4) The hoop stress on the pipeline shall be less than 20% of the specified minimum yield strength of the pipe.
5) If metal piping is used then the temperature range shall be from -10°C to 230°C. For plastic piping the temperature range depends on the plastic.

TABLE VIII. COMPOSITION OF BIOGAS PROPOSED IN THIS STANDARD

Component	**Composition**	
	Community	***Industry***
CH_4	≥ 85 % vol	≥ 85 % vol
CO_2	< 18% vol	< 18% vol
O_2	≤ 1 % vol	≤ 1 % vol
S Tot	≤ 45 mg/Nm^3	≤ 45 mg/Nm^3
H_2S	≤ 10 mg/Nm^3	≤ 23 mg/Nm^3
Ammonia. H_2O	≤ 20 mg/Nm^3	≤ 20 mg/Nm^3
Water dew point	≤ -10 °C	≤ -10 °C
Odorant	Odorant must be added[1]	Not necessary for odorant addition
Particles	No Particle	No Particle

[1]Many standards do not require an odorant for industrial use. It was included in this standard for safety reasons

If the biogas comes from a landfill site these components must follow standard international norms. They are outside the scope of this standard

V. ECONOMIC ANALYSIS

The following is a rough economic model for estimating how much it would cost to produce biomethane to the required standard. The following assumptions were used in this model:

(a) The biogas technology that is used to in this evaluation has the following capacities 3,000, 6,000, 12,000 and 24,000 cubic meters per day (cmd)

(b) The technology is used in the biogas purification is Membrane Separation

(c) The project is set to operate for 15 years, working 330 days per year

(d) Interest payable is 7% per year

(e) Rate of inflation is 3% per year

(f) Energy prices increase by 2% per year, wages increase by 5% per year and Chemicals 3% per year

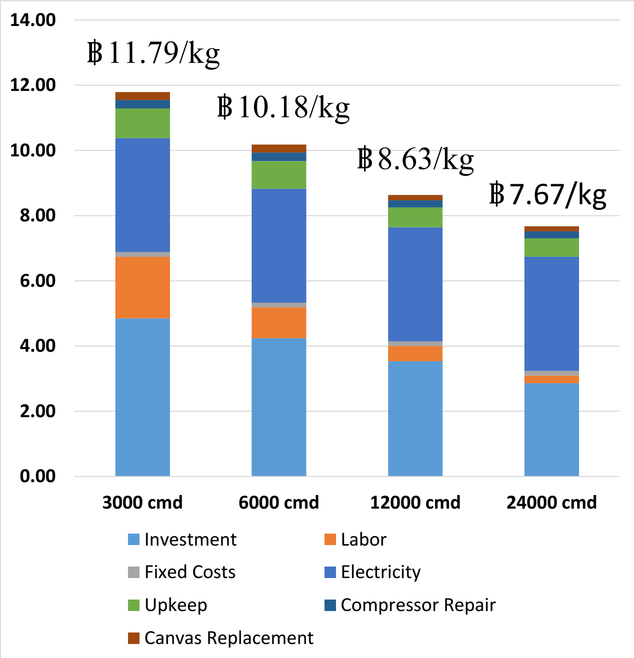

Fig. 2 The estimated cost of the production of bio-methane gas compression

Fig. 2 shows the cost of purifying biogas to 85% biomethane gas, mostly from the compression expense, ranges from ฿7.67 per kilogram of biomethane for 12 tons per day to ฿11.79 per kilogram of biomethane for 1.5 tons per day. ($1 was worth ฿35 (baht) as of 12/4/2016) Presently the price of NGV is 13.50 baht per kilogram and the LPG price is set at ฿22.29 per kilogram. So depending on the quantity of biomethane produced it can compete economically with rival fossil fuels.

A pilot biogas grid has been commissioned in Chiang Mai in the North of Thailand. The average distance from the pipeline to the household was 30m. The following estimates come from a feasibility study into the construction of a biogas grid.

Preliminary Feasibility Study

(a) The total investment needed would be ฿20.03 million for a plant capacity of 600 kg / day

(b) The biogas system would cost ฿6.21 million, the processing system ฿8 million and the pipeline would cost ฿5.82 million

(c) The number of households supported would be 600 households.

(d) Annual O & M costs would be ฿1,054,000

(e) Prices charged for the biogas would be ฿19 per kilogram, equivalent to ฿16 per cubic meter

(f) The expected use of the biogas would be on average 1.0 kg per day per household

(g) The cost of the biogas would be ฿13.20 per kg

(h) The total annual income would be ฿3.564 million per year.

(i) This results in a payback period of 7.3 years.

(j) The Internal Rate of Return works out at 10.12%

(k) For larger systems, the payback period is quicker

The conclusions from this feasibility study is that it is still worthwhile to invest in purified biogas and sell locally even with the present low fossil fuel prices. In the future with increases in fossil fuel prices and improvements in technology the economics will only look more attractive.

VI. Conclusions

In this paper a need for a standard in constructing and operating a biogas grid was identified by the Thai ministry of Energy. A committee was assembled to draft a standard. The new standard was needed since existing pipeline standards did not meet the specific needs of a local biogas grid pipeline.

The primary objective of the standard is to ensure the safety of those who build, operate and use the grid. Acceptable materials, pressures, biogas composition and construction methods are included. The standard was written with the local producers in mind, it is easy to follow and has clear concise instructions. The committee met several times in the spring of 2016 in Bangkok and an outline of a standard was composed. At the end of the summer of 2016 a final version will be submitted to the Thai Ministry of Energy.

An economic feasibility study was carried out which demonstrated the economic case for building a local biogas grid to this standard. The payback period was 7.3 years. A biogas grid is presently under construction in the North of Thailand. When complete and operational a more complete economic picture will emerge. This will be the subject for future work.

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