Different levels of biogas purification for its effective utilization

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Background

In the global efforts to reverse the trend of global warming, various levels of biogas purification are increasingly important to expand its usage and to replace conventional fossil fuels producing significant amount of CO2.

Forecasting the global energy consumption to surge by 66% in 2030 with the global population estimated to grow by 23% from the current 6.5 billion to 8.0 billion in 2030, advanced nations try to reduce 80% of the current level of CO2 emissions by 2030 by promoting nuclear and, renewable energies such as solar, wind, and biomass energies including biogas. Renewables are deemed to be more effective to contain the decrease of CO2 emissions than natural gas producing less CO2 than other fossil fuels still in large demand today. Because of the growing concerns over nuclear safety after Fukushima disaster, many governments shifted their energy policies from nuclear to renewables.

Of all the green energy sources, biomass energy is considered to be more desirable due to its manageability and economy. Unlike solar power or wind power generation, biomass energy production can be controlled easily according to the demand.

Among the biomass energies, biogas has more advantages compared to others: simple purification process; low production cost; generated from sewage sludge and garbage in urban areas, and from agricultural waste, livestock waste, and factory waste in rural areas; no competition with food industry like other bio-fuels such as bio-ethanol and bio-diesel oil. In addition, biogas can be used at its generation sites as fuel for boilers and CHP. Also it can be injected into gas utility pipeline with advanced purification. Biogas is a strong candidate to become an alternative to gasoline and diesel oil for vehicles

This paper reports the current situation of biogas usage and its purification for different purposes.

Aim and method

Demonstrating different types of purification for the effective use of biogas for particular purposes, the report illustrates three cases of biogas purification. In all of the three cases, biogas is produced easily from various types of wastes such as kitchen garbage, sewage sludge, livestock waste, and commercial food waste for significantly low cost thanks to inclusion of the production in the process of the waste treatment.

First case is simple purification of biogas for its utilization in boilers and CHP systems specifically adjusted to run on such gas. This type of purification requires removal of impurities such as H_2S, Siloxane, and moisture down to a certain level to meet the facility specifications set by the manufactures. This doesn't require, by the way, the removal of CO_2 in the purification process.

There are mainly two types of H2S removal technologies. One is biological desulfurization process, and another one is dry-desulfurization process using iron oxide. Biological desulfurization is low running cost but its initial cost is expensive, so suits for large scale plant. Additionally the H2S concentration after biological desulfurization is not enough low and dry-desulfurization is necessary after desulfurization as the final treatment. While dry-desulfurization is comparably high running cost but its initial cost is low and the H2S concentration after dry -desulfurization is enough low, so it is suit for small scale plant or low H2S concentration biogas.

Picture 1 Biogas engine

Picture 2 H_2S remover

The second case is advanced purification to produce bio -methane from biogas for its utilization in NGVs. In many cases, generated biogas can not be entirely consumed on the gas production site such as garbage treatment plants, sewage sludge treatment plants, and dairy and livestock farms. Surplus of simply purified biogas used in the facilities on the production sites are refined further into bio-methane to be used in NGVs. In this case, biogas is highly purified with impurities such as H_2S, Siloxane, and moisture almost completely removed. In this purification process, CO_2 is also removed to some extent, but it doesn't require calorific value adjustment by adding LPG. The law regarding NGVs requires odorization of the gas to the specification stipulated in the law.

There are three types of CO2 removal process. First one is purification by high pressure water process. CO2 solubility increases in increasing the pressure, while CH4 solubility doesn't increase considerably. So making bio gas contact to water under high pressure, most of CO2 solve into water, while most of CH4 remain in the gas phase. Because this process needs a lot of water and large scale water treatment plant, this process is often adopted at sewage plant. This process can remove H2S and siloxane, too. As the good point of this process, the recovery rate of CH4 is high.

Second one is PSA (pressure swing adsorption) process. In this process, pressure in the vessels swings from low to high. When the pressure is high, CO2 is adsorbed on the surface of adsorption agent and when the pressure is low, it is desorbed into gas phase. This process can also remove O2. The recovery rate of CH4 of this process is comparably low, but when the exhausted gas is used for warm the digestion tank, it is not demerit.

Third process is membrane separation. This is comparably new technology and the number of actual plant for biogas purification is not many. The recovery ratio of CH4 is also low, but when the exhausted gas is used for warm the digestion tank, it is not demerit same as PSA.

Picture 3 Biogas Station

Picture 4 Purification Equipment

The third case is super-advanced purification of biogas to be injected into utility gas pipeline, which requires higher purification than NGVs. This can be done when there is a considerable amount of excess biogas generated which is way beyond the consumption capacity at the gas generation sites. In this case, it is also required to odorize the gas to the same specification as the one used for supply gas by utilities. Oxygen, nitrogen, and CO_2 must be also removed to comply with the standard of supply gas set by the utility. In addition , the heating value should be also adjusted by adding LPG to meet gas utility's standard.

Table 1

Item	unit	Crude Biogas	Ex. of Crude Biogas	Standard for CHP	Standard for NGV※3	Ex. of Bio-methane for NGV※3	Standard for Grid injection※4
CH_4	vol%	58－80	59.7	58－80	≧ 97	98.2	—
CO_2	vol%	15－40	37.0	15－40	—	0.6	≦ 0.5
O_2	vol%	0.5－2.0	0.4	0.5－2.0	≦ 4	0.2	≦ 0.01
N_2	vol%	0.5－2.0	0.8	0.5－2.0	≦ 1.0	1.0	≦ 1.0
H_2S	PPM	200－3,000	330	10－100※2	≦ 0.1	< 0.1	≦ 1.0
Siloxane※1	Mg/Nm³	14.53	14.53	≦ 1	≦ 1	≦ 0.005	0
Heat value : HHV	MJ/Nm³	21－32	23	22－32	39	39.3	45
Dew point	℃	0－30	0 ≦	0 ≦	≦ −56	< −60	≦ −60
Odorant Intensity	—	—	—	—	≧ 2,000	3,000	≧ 2,000
Conc. Odorant	Mg/Nm³	—	—	—	—	—	12－16

※1 Siloxane : Organic silicon compound contained in the shampoo and hair conditioner. Siloxane is included in the biogas of the sewage origin.

※2 The limit of the concentration of H2S depends on the CHP manufacturer.

※3 This standard is set by Kobe City

※4 This standard is set by Osaka gas

Oxygen is removed by catalytic combustion adding hydrogen. After cata lytic combustion of oxygen, water is produced, so this has to be removed.

It is difficult to remove nitrogen below 1.0 vol% if biogas includes more. But biogas usually does not include nitrogen and in the case it includes more than 1.0 vol% of nitrogen, th e reason is often contamination of air. So nitrogen concentration can be often decreased by check the plant.

Japanese gas companies are monitoring the composition of biomethane remotely, and in the case that the biomethane composition is out of the standar d, the shutoff valve can be shut automatically and remotely.

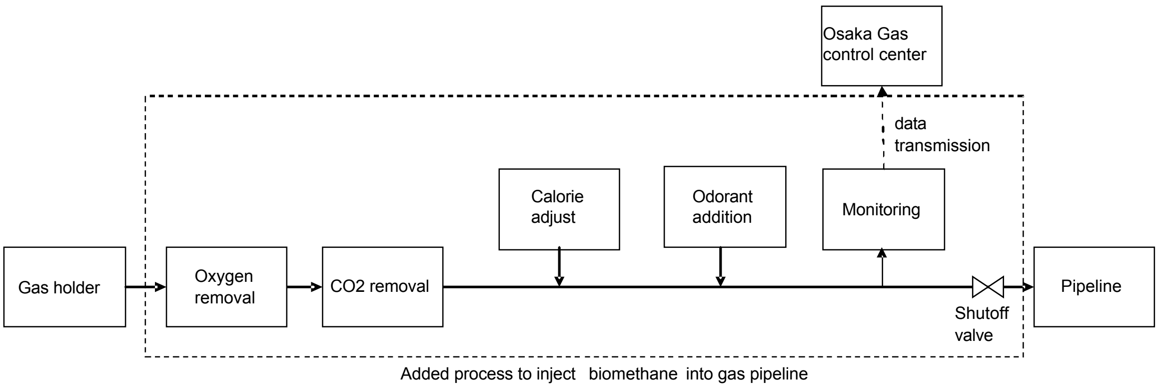

Fig.10 Biomethane composition adjustment system

It has recognized that above system work appropriately and the transportation of the purified biomethene through Osaka Gas's pipeline began in Sep. 2010. 790,000 m3N a year of biomethane will be transported through pipeline, according to the plan.

Result

Promoting biogas utilization on the gas generation sites, Osaka Gas has been developing and marketing various technologies: biogas engines running by combustion premixed with natural gas in a various mixing ratio; its associated purification technology; biological and dry catalyst method to remove H_2S; activated carbon method to remove Siloxane.

Also Osaka Gas has conducted investigations and set standards with respect to introduction of biogas: examination of impact on torque of vehicles by impurities and purification levels for biogas application to NGVs; setting gas quality standard in 2008 prior to the initiation of biogas injection into our grid in 2010.

Conclusion
In order to achieve the most effective use of biogas, it needs to be introduced by purifying it to the standard according to the situation and purposes. The most cost-effective way of using biogas is local consumption at the gas generation sites. Most of the places, however, are not capable of consuming all the gas generated there.

The next option is to put biogas into practical use in NGVs through advanced purification. But in Japan's case, it cannot be an practical option due to the lack of enough NGVs to make the system economically viable.

Another possibility is to inject biogas into utility pipeline with even more advanced purification to match the standard of utility gas as well as fulfilling the requirements of odorization and calorific value adjustment.

In any of the cases above, achieving the effective biogas utilization requires gas purification most suitable to the situation and purpose of biogas application .