6-2 STUDY ON SEWAGE SLUDGE GASIFICATION

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ABSTRACT

Aimed at creating new technology to reduct greenhouse gas emission, the Tokyo Bureau of Sewerage has developed a system generating electricity with a gas engine using biogas generated by pyrolytic gasification of sewage sludge in a fluidized-bed gasifier. A 15t/d demonstration facility was built based on a dehydrated sludge and demonstration tests were run for 3400 hours from 2005. As a result of the use of the present system as an alternative to the sewage sludge incineration system of the past it is possible to more than halve the greenhouse gas volume emitted from the sewage treatment plant. This holds promise of a very major emission reduction and energy saving effect.

KEYWORDS

Sewage sludge; Biomass; Fluidized bed; Gasification; Energy saving; Greenhouse gas

1. INTRODUCTION

In recent years there has been growing interest in the problems of the global environment, especially in the issue of global warming. This has led to intensive research and development of a large variety of energy saving technologies. In Japan, too, the sewage service is a large energy consumer sector. With the further diffusion of the public sewage system and the expansion of advanced treatment, it is predicted that amount of sludge generated, electric power and energy consumption and the greenhouse gas emission levels will increase. To meet these challenges the Tokyo Bureau of Sewerage is engaged in the development and introduction of new technologies and as a planned commitment it has drawn up a global warming prevention program and is aggressively promoting GHG emission reduction measures.

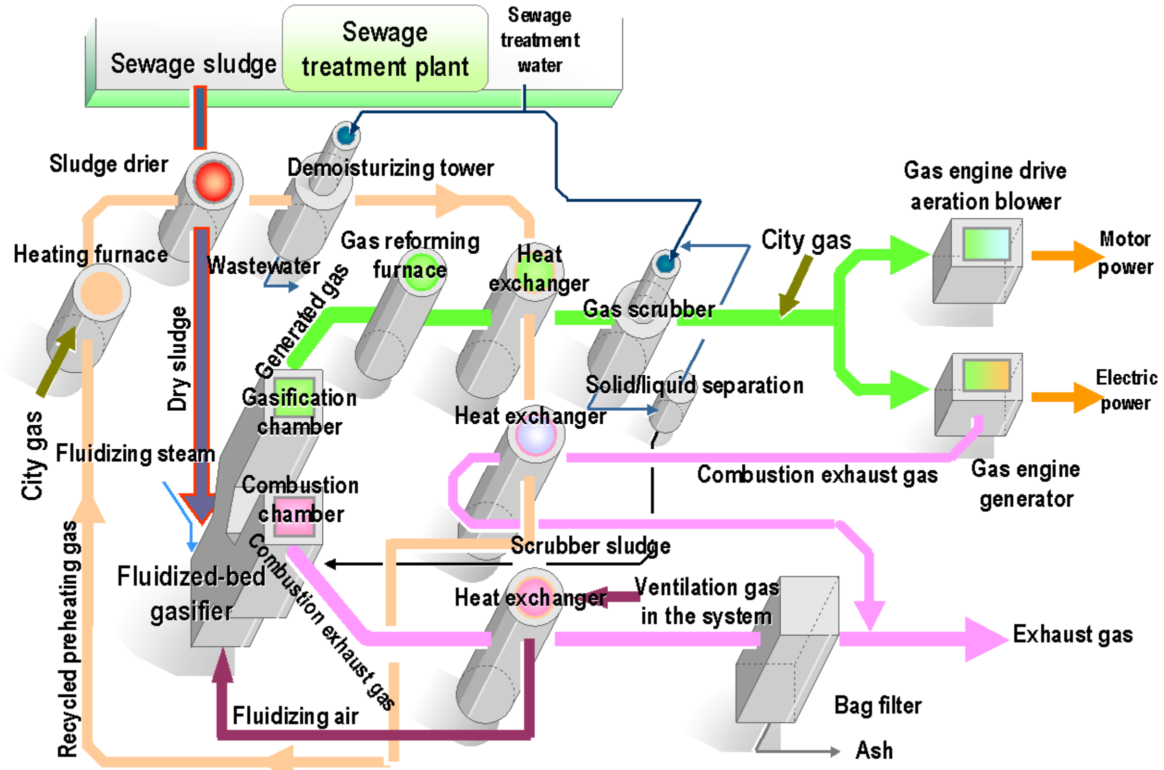
The purpose of this study was to develop a new technology. Attention has been focused on the organic parts of the sewage sludge that has been treated by incineration until the present, and the new technology is designed to convert the energy inherent in the sewage sludge that has remained unused in the incineration process up to now to a usable energy. The use of this technology opens up a promising prospect of a major effect in terms of resource and energy.

2. ENERGY SAVING SYSTEM FOR SEWAGE SLUDGE INCINERATION

Fig. 1 shows the sewage sludge incineration energy saving system. The sewage sludge is dried to a moisture content of 20% in the drier and sent to the gasification chamber of the fluidized-bed gasifier. The fluidized-bed gasifier used in the present system is an internally circulating fluidized-bed gasifier. The dry sludge that has been sent to the gasification chamber is pyrolyzed at a temperature of 650°C - 750°C and reformed with air to a combustible gas (biogas) containing mainly H_2, CO, and CH_4 in a downstream gas reforming furnace at 800 - 900°C. The reformed biogas exchanges heat with the recycled preheating gas for drying the sewage sludge and then washed in a gas scrubber. After this, it is converted to motor power or electric energy by an engine for driving an aeration blower and an engine for generating electric power. The solids, unused carbon, and condensation water removed in the scrubber is fed to the combustion chamber of the fluidized-bed gasifier and submitted to combustion treatment for stabilization. After heat exchange with the fluidizing air and dust removal, the combustion exhaust gas from the combustion chamber of the fluidized-bed gasifier is discharged into the atmosphere.

After the recycled preheating gas for sludge drying has been used for sludge drying it is demoisturized in a demoisturizing tower and decontaminated. After preheating with the above biogas and the gas engine exhaust gas it is heated in the heating furnace to 400°C and used again for sludge drying. High efficiency thus achieved as the waste heat in the respective locations is recovered using recycled preheating gas and used as a heat source for sludge drying.

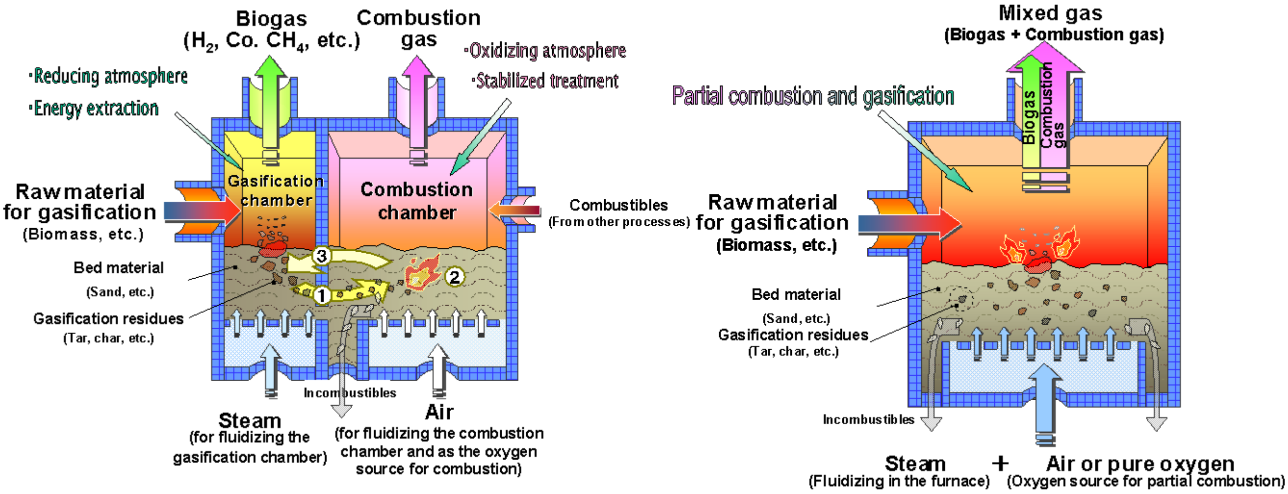
Fig. 1 - Sewage sludge gasification and incineration energy system



3. INTERNALLY CIRCULATING FLUIDIZED-BED GASIFIER

Fig. 2 is a general overview of the internally circulating fluidized-bed gasifier used in the present system. For comparison, it is shown with an overview of the commonly used fluidized-bed gasifier. While the common gasifier is supplied with the raw materials, steam, and the oxygen source such as air in a single space for pyrolytic gasification and partial combustion the present gasifier has a structure that separates the interior between the gasification chamber and the combustion chamber. It is characterized in that pyrolytic gasification and partial combustions take place in different spaces. The gasification chamber is fluidized with steam, and the dry sludge supplied to the gasification chamber is pyrolyzed under a steam atmosphere and decomposed to biogas whose components are hydrogen, carbon oxides and hydrocarbons such as methane, as well as pyrolysis residues such as char, tar and ash. The pyrolysis residues pass through the aperture at the bottom of the gasification chamber together with the fluidizing bed material and are sent to the combustion chamber (Arrow 1 in Fig. 2). The combustion chamber is fluidized with air and the pyrolysis residues sent from the gasification chamber are completely combusted (Arrow 2 in Fig. 2). The temperature of the combustion is maintained at 800 - 850°C with the heat of combustion. The fluidizing bed material heated in the combustion chamber is returned to the gasification chamber (Arrow 3 in Fig. 2) to supply the heat of reaction required for pyrolysis in the gasification chamber. As a result, the raw materials are not partially-combusted in the gasification chamber and their temperature can be maintained at 650 - 750°C. In the commonly used gasifier, the combustion exhaust gas after partial combustion mixes with the generated biogas. Since in the present gasifier, however, the space in which the biogas is generated and the space in which the combustion takes place are separated from each other, the bios gas is not diluted with combustion exhaust gas so that a combustible gas with a relatively high calorific value is obtained. The pyrolysis residues that are difficult to gasify such as char and tar are selectively combusted and this heat is used as the heat source for pyrolysis so that carbon losses are low. Furthermore, as the residues are discharged after complete combustion in the combustion chamber, the ash that is ultimately discharged even though it is gasifier is discharged in the same manner as the incineration ash, which is discharged from the incinerator before. It is characterized in that it has almost no non-combusted components.

Fig. 2 - Internally circulating fluidized bed gasifier (left) and Commonly used fluidized bed gasifier (right)



4. STUDY RESULTS

4.1 Operating results

An experimental facility (Fig. 3) with a treatment capacity of 15t/d (based on dehydrated sludge) was erected and operated for a test time of 3,400 hours starting from September 2005. The demonstration tests were conducted with a treatment volume of 1,750 ton of sewage sludge. The tests were concluded in July 2006.

Fig. 3 - External view of demonstration plant

4.2 Biogas properties

Table 1 shows the composition of the main components in the biogas and the calorific value. Figure 4 shows the time-related changes in the biogas flowrate and the concentration of the main components. Both the flowrate and the composition are stable with variations of +/- a few %. It has been demonstrated that it can be adequately used as a gas engine fuel. The biogas obtained from the pyrolytic gasification of sewage sludge contains, at a concentration of a few thousand ppm, hydrogen cyanide stemming from the nitrogen components in the sewage sludge. In the present system, these components are captured in the scrubbing fluid by wet treatment in the gas refining process and separated out from the biogas. The solution after scrubbing is supplied to the combustion chamber of the fluidized-bed gasifier and the treatment in the process is completed by combustion treatment. It can therefore be concluded that the process has no impact on the environment.

Table 1 - Typical composition of biogas

Flowrate	m3/h(NTP)	200～250
H2	vol%	7～10
CO	vol%	9～13
CO2	vol%	10～12
CH4	vol%	4.0～9.0
C2H4	vol%	0.5～1.0
C2H6	vol%	0.02～0.08
C3H6	vol%	0.02～0.05
C3H8	vol%	0.1～0.2
H2O	vol%	1～1.5
N2	vol%	50～60
LHV	MJ/m3(NTP)	5.0～7.0

Fig. 4 - Time-related change in biogas flowrate and concentration of main components

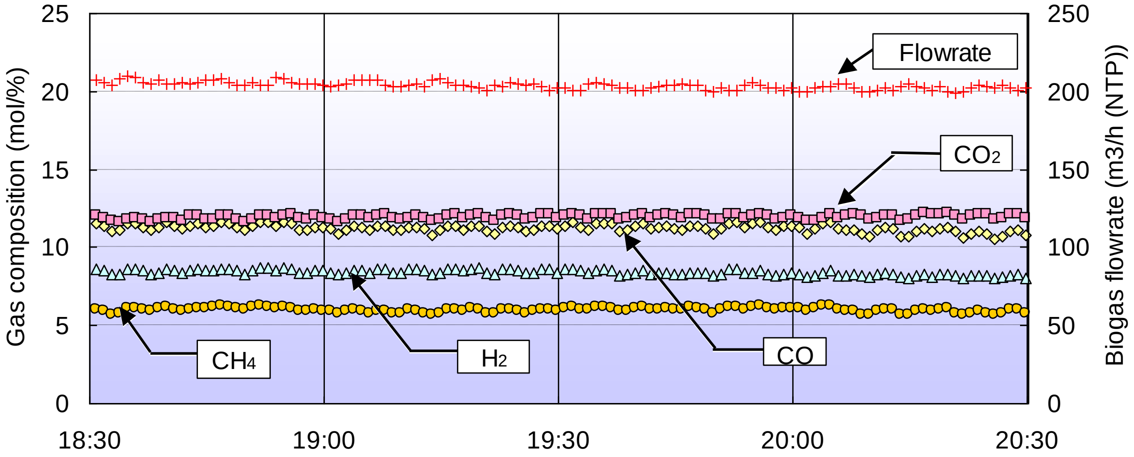
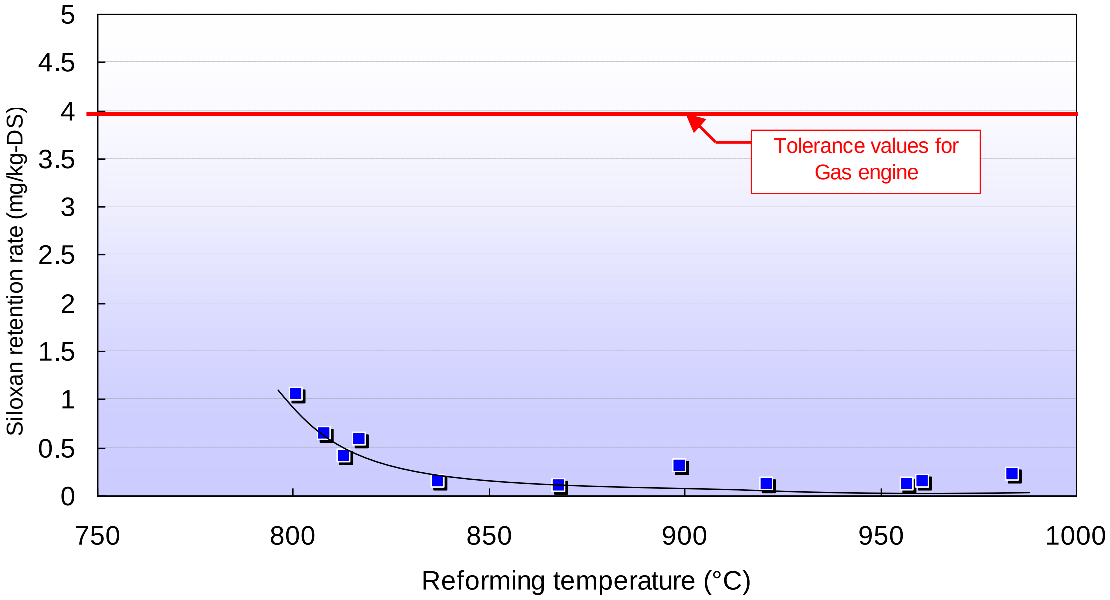


Fig. 5 - Siloxan retention rate in biogas per unit dry raw material feed amount



During power generation using the sewage sludge digestion gas, the siloxan contained in the digestion gas is known to cause problems in the power generating process. With regard to the siloxan that is contained in the biogas generated in the present system, Fig. 5 shows the siloxan retention rate in relation to the gas reforming temperature and the dry material feed amount. The siloxan yield rate depends on the temperature of the reforming furnace: The higher this temperature is the more this rate tends to decrease. The tolerance values for siloxan given by the gas engine manufacturers is around 4mg/kg-DS when converted to the values in this graph. In the present tests they were around 1/3 – 1/4 of this in a gas reforming temperature range of 800°C or higher. It can therefore be assumed that the biogas can be fed to the gas engine without needing to install a siloxan removal system.

4.3 Gas engine drive blower

Fig. 6 shows the time-related changes of the engine speed of the gas engine drive blower and of the blower speed while the biogas is fed. It was possible to confirm that both the engine and the blower speeds were stable and that operation was possible. Also were the load change following behavior, the responsiveness in start, stop and restart and the possibility of control at the level at which it can actually be used as an aeration blower.

4.4. Gas engine generator

The time-related changes in the gas engine's power output when the gas engine generator is operated with biogas are in a figure. Control was possible as the power output of the gas engine generator remained virtually constant. Fig. 7 shows the average changes over 24 hours of the gas engine generator's power output for 10 days, the power generating efficiency, the calorific value of the biogas/city gas mixing rate and the mixed biogas/city gas (mixed gas). Steady continuous operation has been achieved, and on conditions that the biogas/city gas mixing ratio was 50 - 55% on conversion to calorific value, the generating efficiency was around 31 - 33%. It has thus been demonstrated that biogas can be adequately used as a gas engine fuel.

Fig. 6 - Time-related changes of gas engine drive blower speed

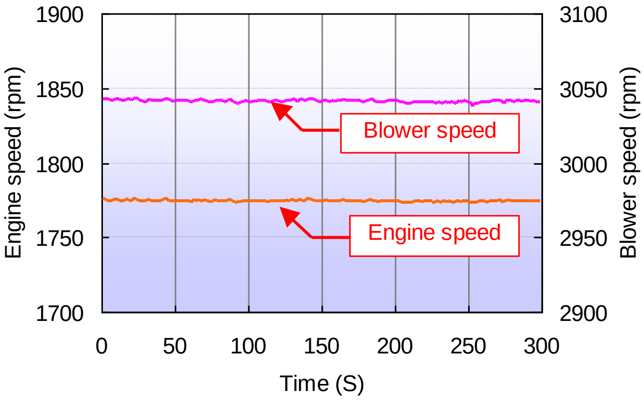


Fig. 7 - Time-related changes of gas engine generator output

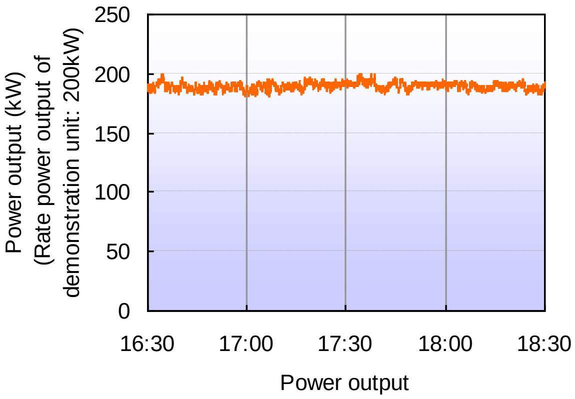
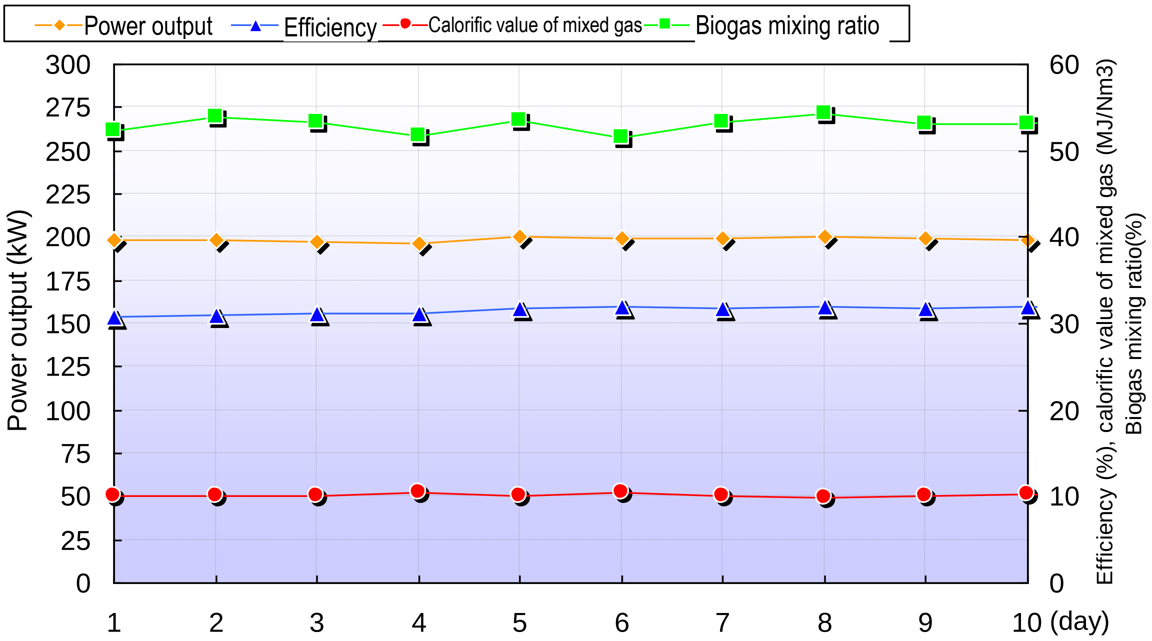


Fig. 8 - Continuous operation of gas engine



5. PURCHASED PRIMARY ENERGY CONSUMPTION AND GHG REDUCTION EFFECT

Based on the results of the experiments, the effect arising from the introduction of the present system in a sewage treatment plant has been calculated. The calculation conditions are based on the case that the power generated with the present system is 3,000kW using a mixed biogas/city gas, with the purchased electricity amount being roughly 3,800kW and the sewage treatment plant having a dehydrated sludge output on a scale of 100t/d (see Fig. 9). As a result, as shown in Figs. 10 and 11, comparison with the previous combustion treatment shows a roughly 60,000GJ/year reduction (19% reduction against the conventional system) effect for the purchased energy amount of the sewage treatment plant. Moreover, the calculation results have evidenced a roughly 17,000t-CO_2/year reduction (55% reduction against the conventional system) of GHG emissions. The fact that the GHG reduction effect is greater than the energy reduction effect is due to the suppression of N_2O formation, a substance that has a global warming coefficient 310 times that of CO_2. In recent years, high-temperature incineration has been used for sludge incineration treatment in order to reduce N_2O emission. With the present system, however, the gasification chamber in which the raw material is heat-treated initially, is almost anoxic and since N_2O formation is suppressed to the extreme it is possible to achieve a GHG reduction effect of approximately 4,600t-CO_2/year (equivalent to a 25% reduction) also in comparison with high-temperature incineration. The energy that is inherent in the sewage sludge has until now been converted to heat and has been lost unused from the sewage treatment plant. It is fair to assert that this system makes a substantial contribution to the protection of the global environment by converting this energy to an energy form capable of being utilized.

Fig. 9 - Conditions for Calculation of Usage Benefits

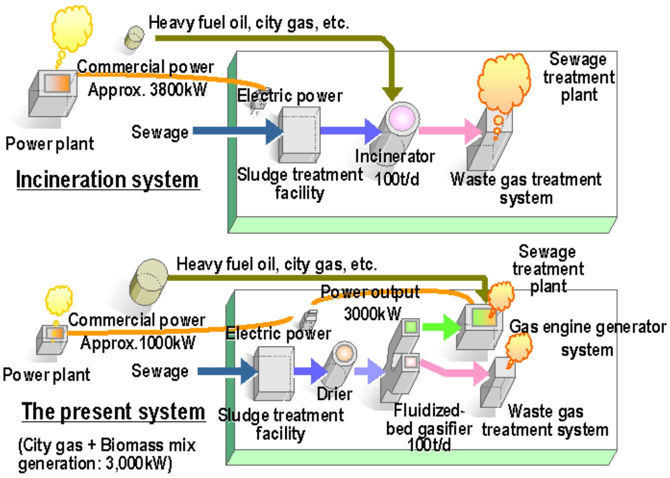


Fig. 10 - Comparison of primary energy consumption

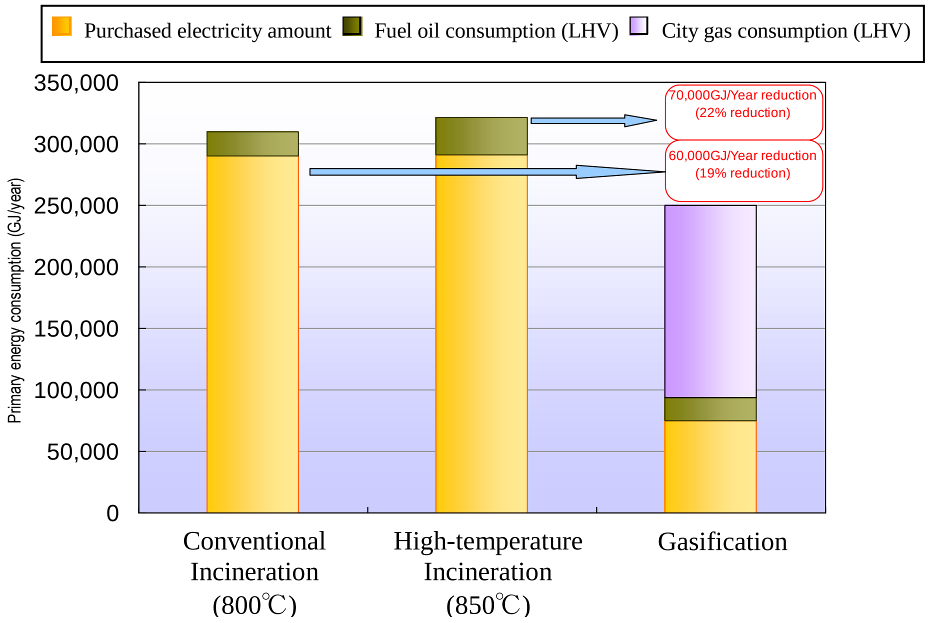
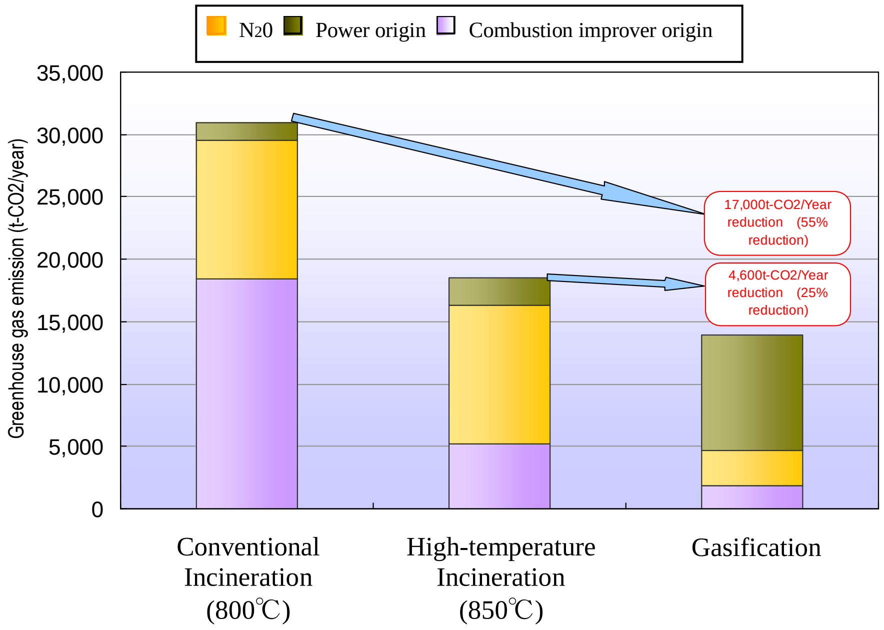


Fig. 11 - Comparison of GHG emission levels



6. CONCLUSION

It has been confirmed that as a result of the effective use of the unused energy that used to be released into the atmosphere as heat from the sewage sludge incineration until the present, a roughly 19% reduction of purchased primary energy can be achieved as a reduction on maintenance and operation costs, and a roughly 55% reduction in GHG emissions as a measure to prevent global warming. The Tokyo Bureau of Sewerage is intent of developing this system for practical use in an endeavor to reduce greenhouse gas emissions. Furthermore, research will be undertaken for further advances in energy saving and a greater reduction in greenhouse gas emissions by utilizing a mixture of woody biomass such as wood chips and sewage sludge.