Green Energy Production from Municipal Sewage Sludge in Japan

Japan Sewage Works Association

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Foreword[1]

Sewage treatment is completed by proper treatment of sludge and its sustainable recycle. Japan has made lots of efforts to recycle sludge as the reclamation site capacity is limited. The following Figure 1 shows how much recycling rate has increased over the past twenty years.

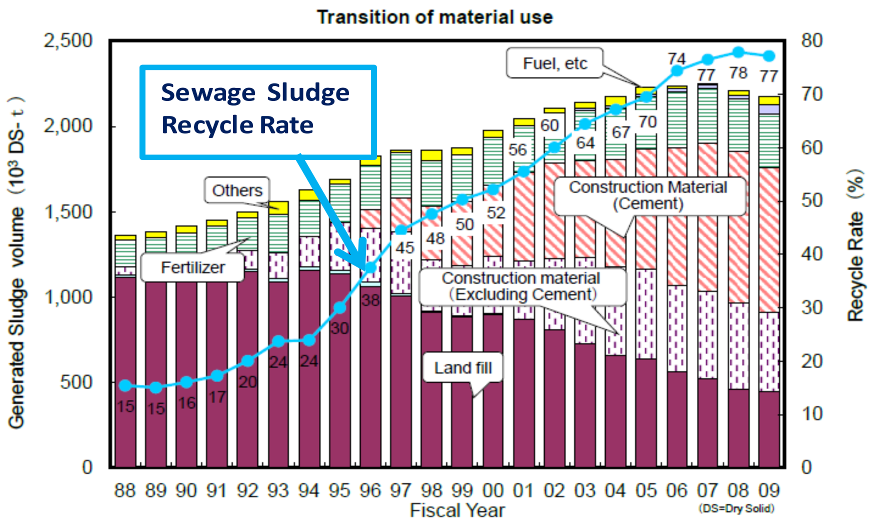
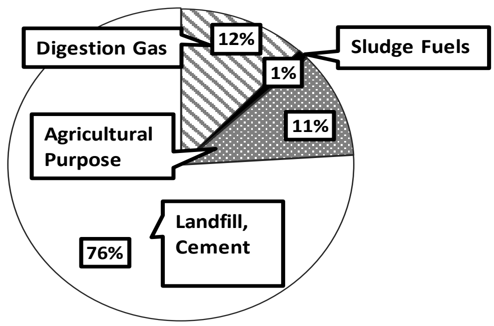


Figure 1 Trend of Sewage Sludge Recycle

According to Figure 2, recycling rate in Japan reached 77% in 2010 on dry solid basis. Forty five percent of recycled sludge was recycled as construction material and 30% as cement material. In the case of construction material, it uses only inorganic content of sludge. If we look at only organics, the recycle rate is down to 24%.[2] Energy use from organics in sludge is merely 13%.



[1] P.72,73 Japan Sewage Works Association (2012) '平成 24 年度下水道白書 日本の下水道' (The Sewage Bluebook 2012)
[2] Sum of Digestion Gas 12 %, Sludge Fuels 1%, and Agricultural Purpose 11%

Figure 2 Recycle Rates of Organics in Sewage Sludge

Considering the issues of global warming and energy dependence on foreign fuel with crippled nuclear power plant reputation by the Great East Japan Earthquake in 2011, the promotion of green energy has become one of the national goals. Municipal sewage sludge is indeed highly potential untapped resource. For these reasons, national government has implemented several policies to advance energy recycle. They include subsidy to development of new technology, creation of a guideline for the use of in-sewer sewage, feed-in tariff, and renewable energy certificate. From this context, this paper provides four leading projects of green energy production from municipal sewage sludge, namely, biochar production at Hiroshima City, gasification at Tokyo Metropolitan Government, biogas use as vehicle fuel and city gas at Kobe City, and biogas generation from a mix of food waste and sewage sludge at Kurobe City.

Case 1) Biochar Production in Hiroshima[3]

Background

In 2007 when Hiroshima started considering biochar, the generated amount of sewage sludge in Hiroshima was 58,000 tons per year. Out of this sludge, 31,000 tons were recycled as either compost or cement material. The remaining 27,000 ton was used for reclamation after incineration. However, Hiroshima faced three problems. Firstly, reclamation was not sustainable as it is environmentally unfriendly with lack of site capacity. Secondly, the incinerators ended their useful life and needed much money for their renewals. Thirdly, composting and cement use would face uncertainty of market leading to unsecure disposal of sludge. Under these circumstances, Hiroshima started working on the bio-char production project.

Project Summary

Hiroshima contracted with a joint venture of J-Power, Tsukishima, Meta Water, and Tsukishima Maintenance Hiroshima on DBO (Design-Build-Operate). The design and construction period was from March 2009 to March 2012, and its operational period is from April 2012 to March 2032. The contractor handles 28,000 tons per year of dewatered sludge. The plant has two trains of production line with capacity of 50 tons per day each.

[3] This part is quoted from Hiroshima City Sewerage Department (2013), ‘広島市の下水道汚泥燃料化事業について’ (Sewerage Sludge Biochar Project in Hiroshima), Reuse and Recycle (再生と利用), No.138; Japan Sewage Works Association , Tokyo

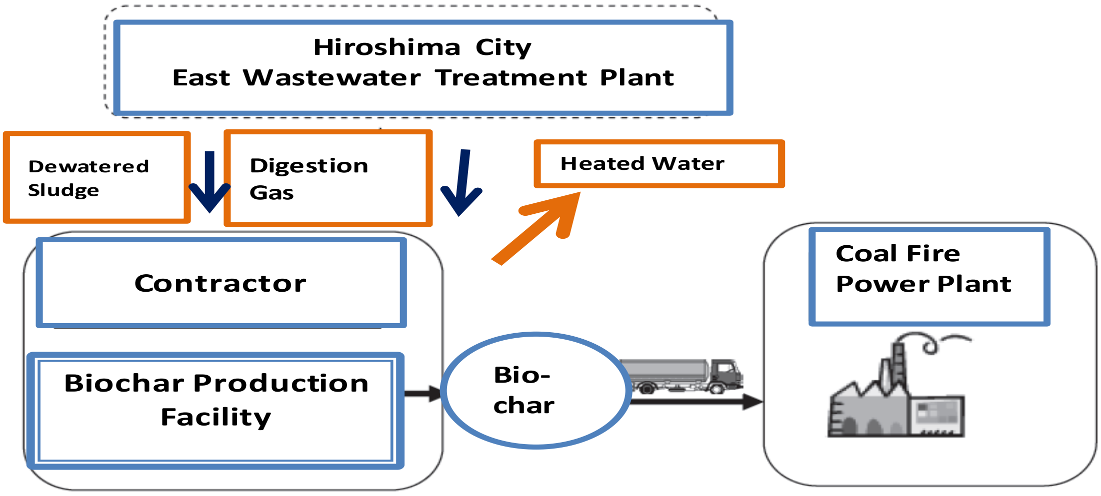


Figure 3 Schematic of Project

Outline of Production System

The project operated a low temperature carbonization technology. The technology had been developed by J-Power, Tsukishima, Meta Water, and Japan Sewage Works Agency between 2004 and 2007. The temperature range is 250 to 350 Celsius degree. The strong points of low temperature biochar production are biochar with high calorie, low risk of self-ignition, and low odor level. The system flowchart is shown in Figure 4.

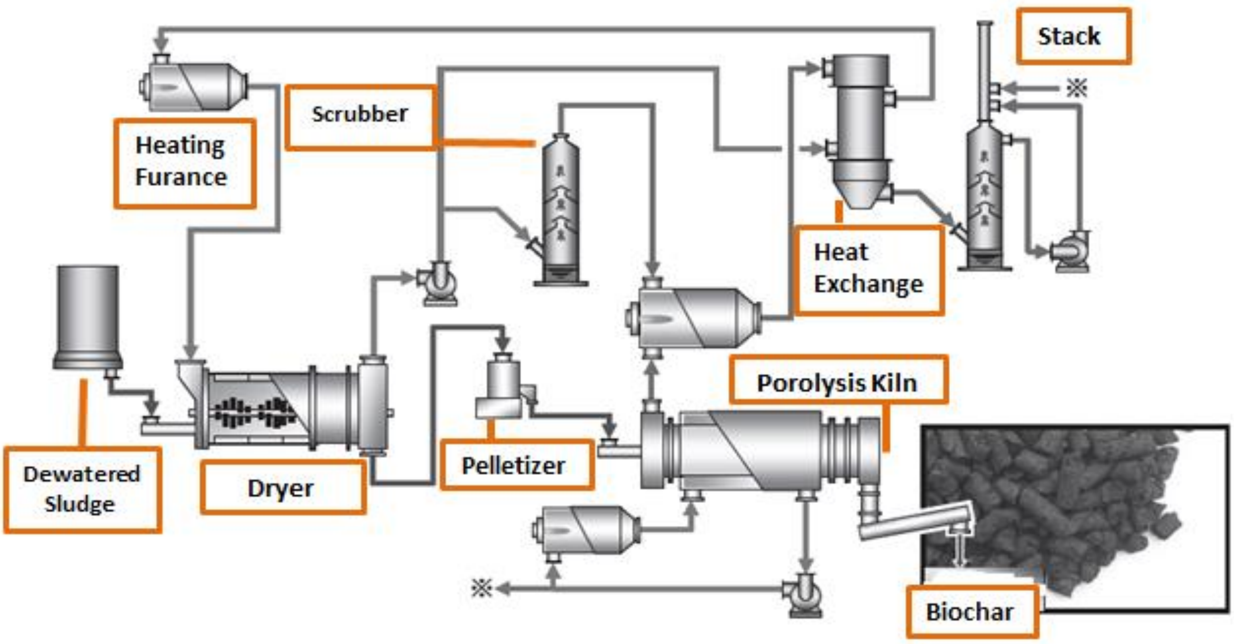


Figure 4 Flowchart of Low Temp Biochar Production System

Reduction of GHGs

The utilization of biogas as fuel for biogas production has reduced 8,700 tons of CO2 per year. The number of reduction was around 12% of total emission of wastewater service in Hiroshima. Furthermore, the utilization of biochar at a coal fire power plant expects to reduce 6,400 tons of CO2 yearly. Thus, total GHGs reduction is currently 15,100 ton per year in CO2.

Operation Status

Since the start of operation in April 2012, as of September 2012, 14,000 tons of dewatered sludge has been processed with the production of 2,300 tons of biochar. The operation has been underway without problems.

Conclusion

By means of the introduction of biochar production system, Hiroshima achieved full recycle of sewage sludge while reducing GHGs emission considerably. Biochar production from sewage sludge contributes to recycling and prevention of global warming.

Case 2) Gasification at Tokyo Metropolitan Government[4]

Background

In 2006, Tokyo Metropolitan Government (TMG) made a program to reduce GHGs by 25% from Tokyo area between the year 2000 and 2020. In fact, wastewater service activities occupy around 40% of GHGs emission from entire TMG public service. Therefore, they are strongly obliged to cut down the GHGs. Under this situation, gasification of sewage sludge started as a key technology.

Outline of Gasification System

Gasification is a process that converts organic materials into gas mixture. This is achieved by reacting the material at high temperatures, without combustion, with a controlled amount of oxygen. The gas mixture is a fuel. The fuel gas is used for drying sludge and power generation by adding city gas to stabilize output power. In the heat recovery furnace, the temperature goes up to 900 Celsius degree leading to little N2O gas generation. The N2O gas has 310 times more impact 'per unit weight' (Global warming potential) than carbon dioxide. Therefore, gasification contributes to reduction of GHGs as well as producing green energy.

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[4] Tokyo Metropolitan Government (2012), ‘清水再生センター汚泥ガス化炉の技術評価について’ (Technical Evaluation of Sludge Gasifier at Kiyose Water Reclamation Center), Reuse and Recycle (再生と利用) , No.137

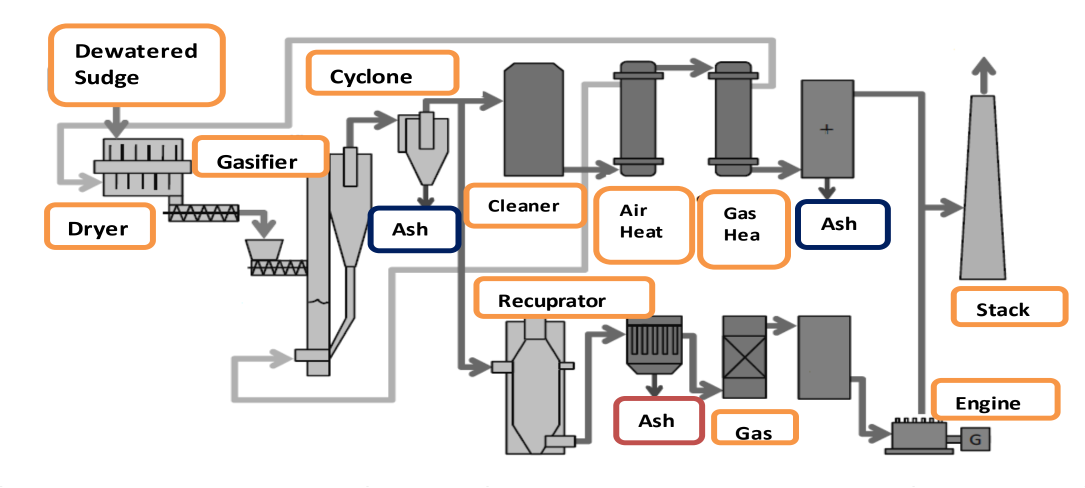

Figure 5 Flowchart of Gasification

Table 1 Specification of Main Machine Operation Status

Main Instrument	Details
Dryer	Capacity 4,167kg/h, Dia 2.3 x L 9.5m
Gasifier	Dia 0.96m x H10m, Temp: 800 °C
Heat Exchange	Dia 3.5 x H17.7m, Temp: 900 °C
Recuprator	0.77m x H5.3m, Temp : 1000 °C
Dust Remover	Gas 720m3/h, Entry Temp : 200°C
Gas Condition	Gas 720m3/h, Reaction Temp 400°C
Engine	Gas Combustion 150kW

Since the start of operation in July 2010 till September 2012, the operation has been smooth except a temporary suspension due to initial trouble shooting and the Great East Japan Earthquake in March 2011. Despite of the unexpected circumstance, operational days were more than 80% of the year. Looking at power generation, although the target for generation of power at TMG was met, more than half of the actual generated power came from the city gas in Tokyo. This is partly because of the unexpectedly lower calories of dewatered sludge.

Table 2 Power Generation

	Target	2010	2011
Total Gas Generator	Over 100kw	137kw	145kw
derived from Sludge Gasficication	-	62kw	52kw
derived from City Gas	-	75kw	93kw

As shown in Table 2, GHGs' emission met the target value too, but still has a possibility to be reduced if dewatered sludge calorie can be raised as expected. Compared with former incinerator, GHGs emission reduced significantly as heat recovery furnace was operated at 900 Celsius degree constantly leading to massive cut of N2O.

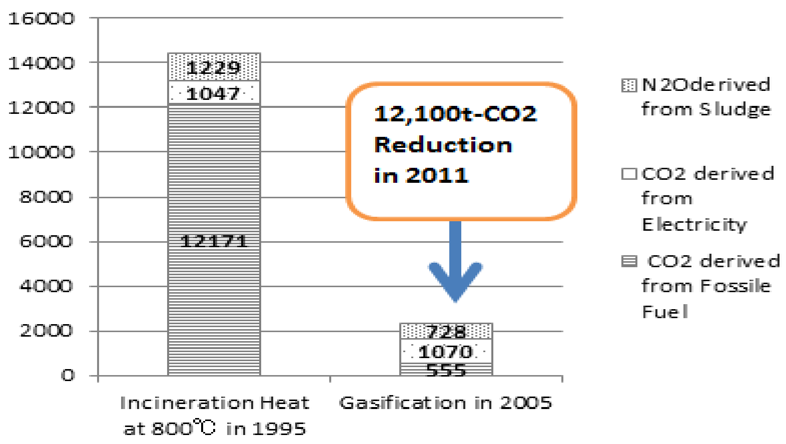

Figure 6 Comparison of GHGs emissions between incineration and gasification

Regarding air pollutant emission as seen at Table 3, all the parameters cleared the regulatory requirements.

Table 3 Concentration of Emitted Air Pollutants

		Particulate Matter	Nox (ppm)	Sox (ppm)	HCL (ppm)	Dioxin (ng-TEQ/m3)
Stack	Permit	0.15	250	6.42	700	5
	Mesured	0.008	19.4	0.106	<3	0.000341
Exhaust	Permit	0.05	500	N.D	N.D	N.D
	Measured	0.004	144	N.D	N.D	N.D

Conclusion

Gasification has been successfully operated regarding operational days, power generation, GHGs reduction, and air pollution control. However, reduction of the city gas use needs further improvement.

Case 3) Biogas Use as Vehicle Fuel and City Gas in Kobe[5]

Background

Kobe has treated 510,000 m3 per day of sewage at six WWTPs. All the generated sludge goes through a digestion process producing 37,000 m3N per day of biogas. However, its use was limited within WWTPs such as heating digester tanks. This is due to the poor quality of biogas as fuel. For the purpose of reducing the GHGs by making more use of biogas, Kobe has started using it as auto fuel since 2008. Moreover, in 2010, Kobe started supplying it to the city gas network. The quality requirement of the city gas is much stricter. For this reason, purification of biogas is necessary.

[5] Kobe City Sewage Works and River Management Department, ‘神戸市東灘処理場再生可能エネルギー生産・革新的技術実証事業 KOBEーグリーン・スイーツプロジェクトー(East Nada Treatment Plant Sustainable Energy Project in Kobe), Reuse and Recycle (再生と利用), No.134 Reuse and Recycle (再生と利用) , No.137;

Biogas Purification System at WWTP

The adopted method is a high pressure water scrubbing. The schematic is shown in Picture 7. The biogas from digester is compressed to 0.9 MPa and is injected into the bottom of the scrubber while water is sprayed from the top of the column. The obtained CH4 purity is over 97%. The purified gas is stored at a medium pressure holder. Then, it is sent to a further purification plant for injection to 1) the city gas network, 2) a neighboring gas station for the use as vehicle fuel, and 3) the use within the WWTP for heating digester tank and air conditioning.

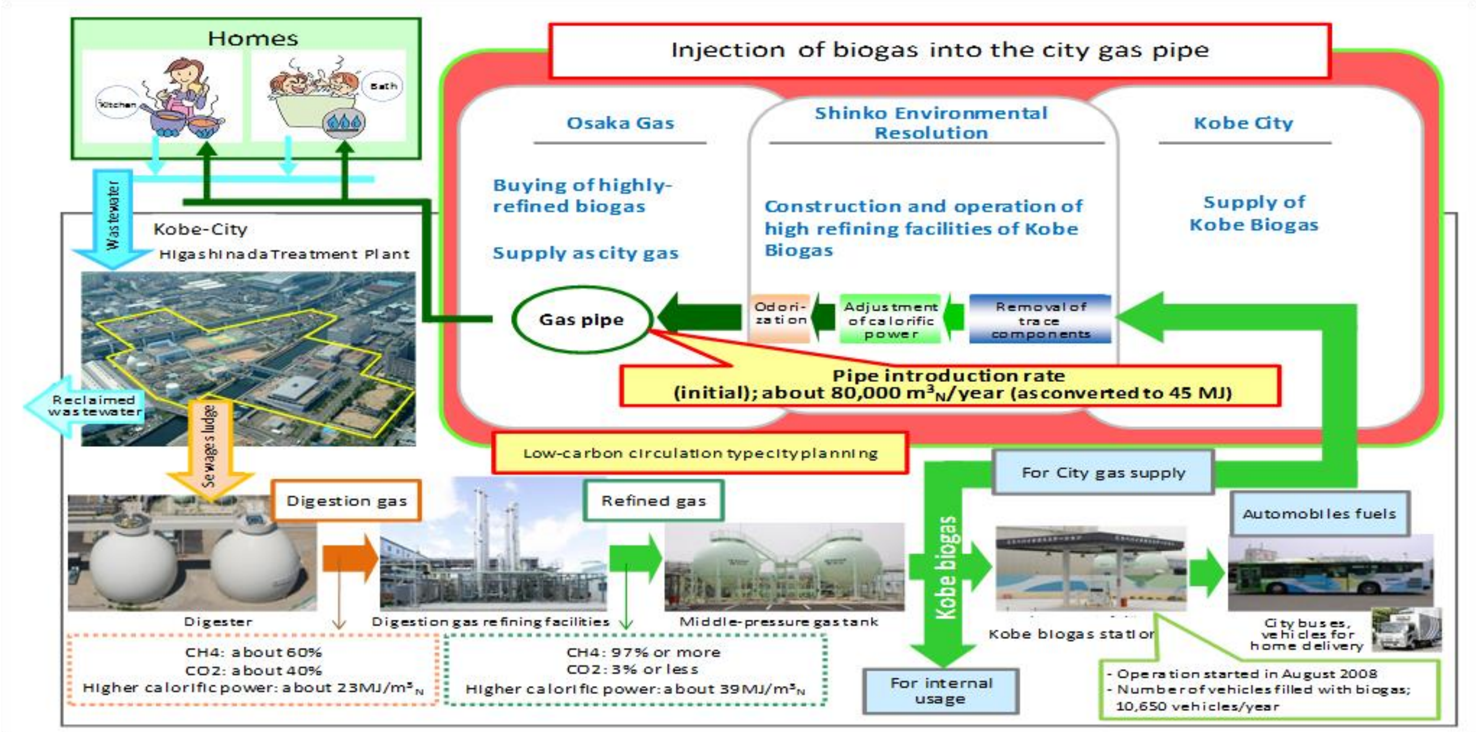

Figure 7 Biogas Purification at Kobe WWTP

Project for the Biogas Use as City Gas

In 2010, Kobe City, Osaka Gas, and Kobelco Eco Solutions started a new project for a full recycle of biogas. Each role includes that Kobe City supplies purified biogas, Kobelco further purifies the gas up to the quality of city gas of Osaka Gas, and Osaka Gas buys the twice purified biogas.

Figure 8 Purification and Injection Facility for City Gas Use

At the Higashinada WWTP, the amount of biogas generation is about 10,000m3N/day in the beginning. It becomes 6,000m3N/day after the first purification by Kobe at the WWTP.

1,300m3N/day out of 6,000 m3 N is used as vehicle fuel, 2,700m3N/day is used within the WWTP, and the remaining 2,000m3 N/day is used for city gas after the second purification.

This project produces 800,000m3N/year city gas from biogas. It is equivalent to the gas consumed yearly at 2,000 households achieving the GHG reduction by 1,200 tons of CO2 per year. The figure 9 shows the growth of injection as planned.

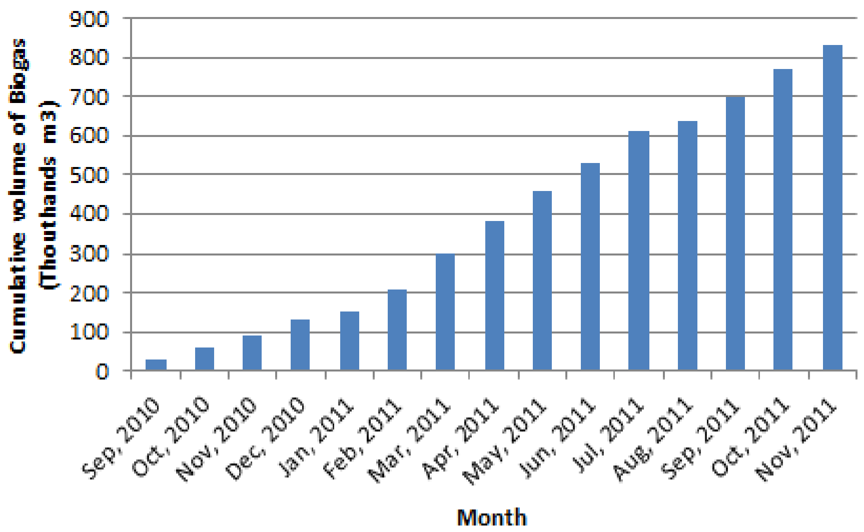

Figure 9 Total Amount of Injected Gas to Osaka Gas Network

Conclusion

Kobe has achieved a full recycle of biogas by introducing the systems for vehicle fuel use and injection to city gas. Supply to the city gas network can absorb the unstable imbalance between demand and supply of generated biogas at WWTPs.

Case 4) Biogas Generation from a Mix of Food Waste and Sewage Sludge in Kurobe[6]

Background

As of year 2012, Kurobe has faced the rehab needs for its aging sludge treatment center. The center was treating sludge from onsite sewage treatment systems and on-site human waste storage tanks. The issue was whether the center would be renewed or disused. In fact, the city sewer network was expanding, and the sludge generated from a centralized WWTP was either recycled as cement material or disposed at reclamation sites. However, the recycle and disposal were costly and it had a risk of undertakers' business closure. Under these circumstances, in 2003, Kurobe decided to start a new project with the closure of the sludge treatment center. The new project has intended to maximize the green energy production in the city. The project has been underway on Private Fund

[6] Kurobe City Water and Wastewater Department (2012), '黒部市下水道バイオマスエネルギー利活用施設整備運営事業の概要について' (Kurobe City Wastewater Biomass Energy Use Project Summary), Reuse and Recycle (再生と利用), No.134

Initiative (PFI) contract.

Project Summary

The thickening facility of Kurobe WWTP accepts sewage sludge generated from onsite and centralized treatment systems, and waste coffee from a factory. Food waste disposers at individual households are also introduced to increase the calories of sludge. The PFI contractor is a special purpose company (SPC) sponsored by Swing Cooperation and Ebara Cooperation. The SPC digests the sludge and uses the biogas energy for heating the digester and dryer of the sludge, while providing hot water to a foot bath facility and generating electricity. The project schematic is shown in Figure 10 and the summary of PFI is in Table 4.

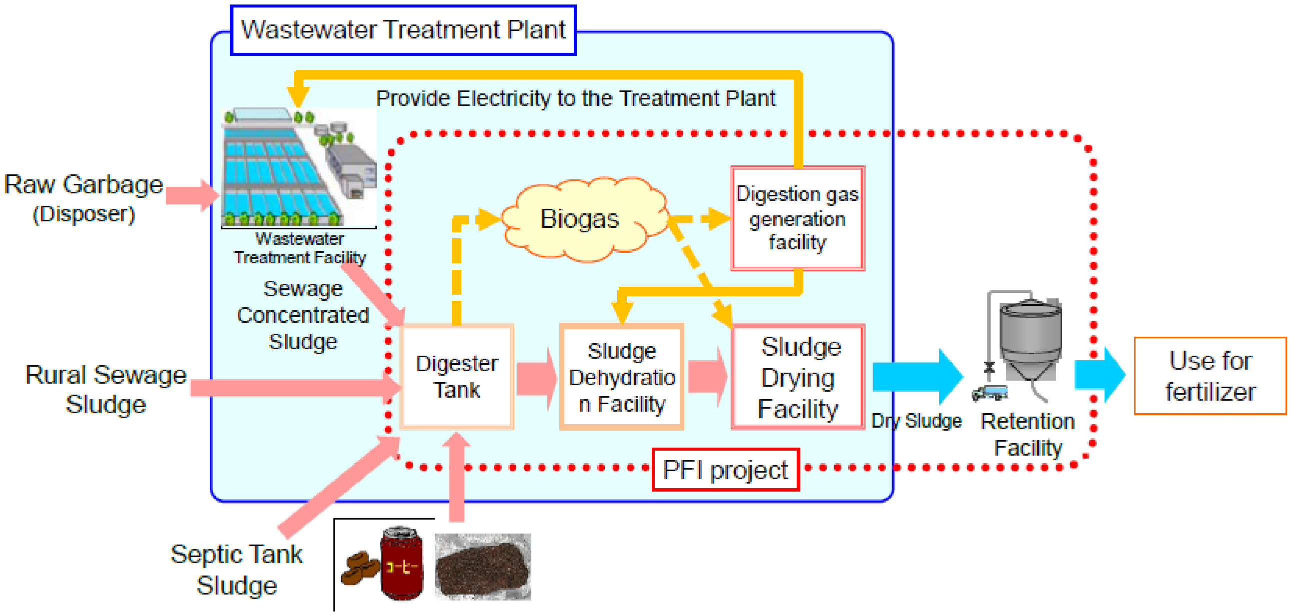

Figure 10 Schematic of Project

Table 4 Summary of PFI Scheme

(m3/year)

Planned Amount of Sewerage Biomass (2025)	1. Thickened Sludge of large WWTP	24,346
	2. Thickened Sludge of small WWTP	1,080
	3. Thickened Sludge on-site System	134
	4. Thickened Sludge from Food WasteDispose	668
	5. Coffee Waste	2,844
	Total	29,132
Biogas Uses	1. Micro-Gas Turbin for interal use	
	2. Boiler for digester and dryer	
Dried Sludge Uses	1. Raw Material for Fertiliser	
	2. Alternative fuel at coal thermal	
GHGs Reduction		1,000t /y
Power Generation	380,000wh/y	

Notable Technology and Aspect

Mixing Tank before Digester

Thickened sewage sludge and waste coffee are mixed, shredded, and made into slurry. This process makes fermentation easier in the subsequent digester.

Figure 11 Mixing Tank

Micro Gas Turbine

Part of biogas is fed to a micro gas turbine with a capacity of 95kwh. The engine is remote-monitored around the clock enabling preventive maintenance. It is under full operation as of January, 2012.

Figure 12 Micro Gas Turbine

Communal Foot Bath Facility

This facility is within the premises of the WWTP and the water is heated by biogas. It intends to welcome citizens to WWTP and publicize the recycle project. At high season, more than one thousand citizens enjoy the foot bath a month.

Figure 13 Communal Foot Bath Facility

Introduction of Food Waste Disposer

Introduction of food waste disposer intends not only to raise sludge calories but to deal with garbage collection problems. The population of Kurobe has been aging and it is snowy in winter. The elderly had difficulty in taking their garbage to collection spots. For this reason, the city subsidizes 30,000 yen per unit for those installing food disposers in their kitchens.

Conclusion

Kurobe reduced the risk of losing the treated sludge destination by starting a new PFI project. In addition, recycle of biogas and dried sludge contributes to the GHGs reduction by as much as 1,000 tons of CO_2 per year.

Reference

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