From Waste to Energy - Development & Use of Renewable Energy in Sewage Treatment Facilities

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Abstract. The Drainage Services Department (DSD) of the Government of the Hong Kong Special Administrative Region undertakes the responsibility for flood prevention as well as sewage collection, treatment and disposal in Hong Kong. Over the years, with a vision "To provide world-class wastewater and stormwater drainage services enabling the sustainable development of Hong Kong", DSD has been, in the course of operation, adopting various energy saving technologies and utilizing various forms of renewable energy such as biogas, wind and solar energy wherever practicable. This paper highlights the recent developments, challenges and outlook of utilization of renewable energy in DSD, including combined heat and power (CHP), co-digestion of food waste with sewage sludge and photovoltaics (PV).

Keywords. sewage treatment; combined heat and power; co-digestion; photovoltaics

1. Introduction

With the mission of improving drainage services in a cost effective and environmental responsible manner, DSD has been promoting energy efficiency via two approaches, namely implementing various energy saving measures, and making use of renewable energy in its sewage treatment works (STWs) and sewage/stormwater pumping stations. Over past years, several renewable energy initiatives have been studied and implemented. For instance, DSD has progressively installed 5 CHP and 1 micro-turbine plants in its STWs since 2006 for capturing the energy in biogas which is produced as a by-product in the sewage sludge treatment process. At present, the total installed capacity of renewable energy systems in DSD is around 12 MW and the equivalent energy saved by the systems is over 29 million kWh per annum.

2. Biogas Generation and Combined Heat and Power Technologies

Currently, around 93 percent of the some 7.2 million people in Hong Kong are served by public sewers, resulting in more than 2.8 million cubic meters of wastewater being collected and treated to different levels (ranging from primary, chemically enhanced primary, secondary to tertiary treatment) each day. About 900 tons of treated sewage sludge, or biosolids, are produced every day from DSD's STWs. Biosolids have a high calorific value, and typically, one kilogram of dry biosolids contains about 18,000 kilojoules. Its energy content is approximately 40% of that for gasoline. Biosolids are clearly a valuable renewable energy source.

DSD has adopted the anaerobic digestion process for treatment of biosolids at its four major regional secondary STWs. With the use of CHP/micro-turbine plants for co-generation, biogas produced from the anaerobic digesters is largely transformed into useful electricity and heat energy. The electricity is used to power E&M equipment in STWs, whereas the recovered thermal energy is used to heat up and maintain the sludge inside the digesters at a temperature of about 35°C, for maintaining the performance of the digestion process.

The CHP plants installed in DSD's STWs are all running on reciprocating engines. From an engineering point of view, this kind of engines has the merits of quick starting and good part-load efficiencies.

Figure 1 indicates the normal operating process of a CHP system.

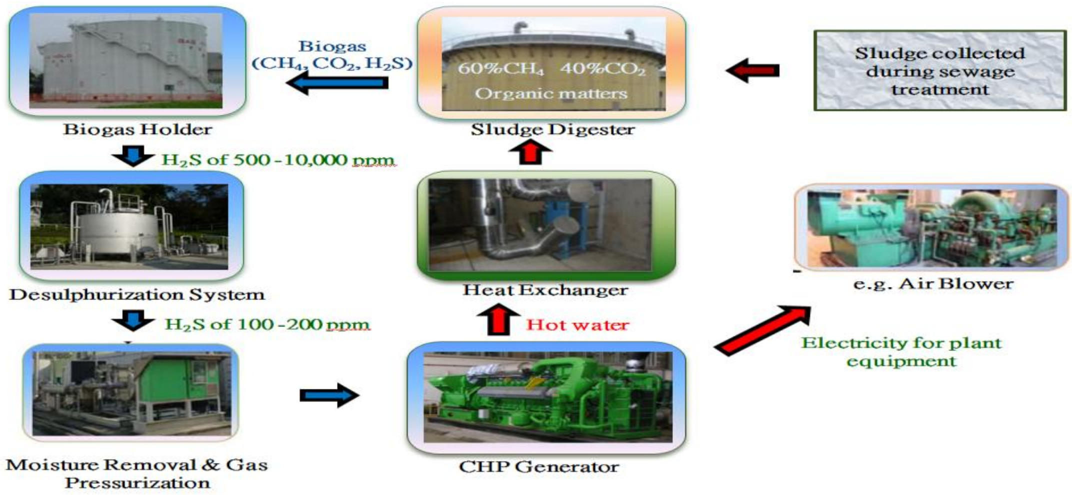

Figure 1: CHP system flow diagram

Biogas generated in sludge digesters is first transferred to and stored in biogas holders. After desulphurization and moisture removal, the purified biogas is fed at a constant pressure into the CHP plant. The energy stored in the biogas is then converted into thermal energy and mechanical energy which drives a synchronous generator for producing electricity to meet part of the power demand of the STW, with the heat recovered from the electricity generation process for maintaining the temperature of the sludge inside the digester.

The first CHP generator in DSD was commissioned in 2006. It has a capacity of 330kW. Between 2006 and 2014, four more CHP plants and a micro-turbine generator were installed, bringing the total capacity to 3,650 kW. The graph in Figure 2 presents the associated timeline of installation. All CHP plants in DSD are now operating in on-grid configuration (i.e. connected to operate in parallel with the power supply grid). Notably, the CHP plant in one of DSD’s secondary STWs, with a capacity of 1.4 MW, is the largest high-voltage grid-connected generating unit operating in Hong Kong.

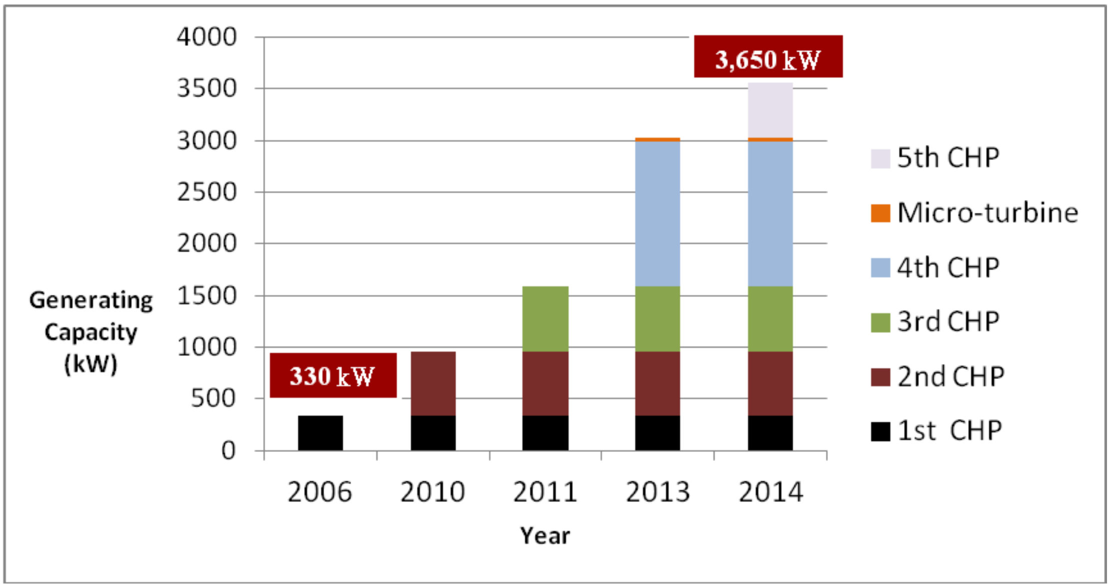

Figure 2: Timeline of installation of CHP plants and micro-turbine generator in DSD

In 2014, the equivalent energy recovered from use of biogas in DSD's STWs was more than 28 million kWh, which is equivalent to the annual electricity consumption of some 3,100 four-member families and reduction of emission of almost 20,000 tons of CO_2.

DSD's CHP systems did not get implemented without meeting some challenges. For example, if a CHP generator serves to power equipment that constitutes a large portion of electricity load (e.g. effluent pumps), the on-off switching of the equipment sometimes cause nuisance tripping of the generator. This is because the generator is unable to reduce its operating frequency instantaneously and its protective device is thereby triggered. This accordingly causes temporary shutdown of the generator. A large pool of loading can help modulate the impact of switching of a single piece of equipment. As far as heating load is concerned, given that the sludge digesters in STWs require thermal energy for maintaining its optimum digestion temperature of some 35℃, the large amount of heat captured by CHP generators can perfectly be capitalized to heat up the sludge in winter days. However, in summer days, as the digesters do not need such a large amount of thermal energy, the heat generated by the CHP generators may not be able to be fully utilized and better utilization is now being explored, such as the use of tri-generation.

To enhance the utilization of the biogas generated, which is on the rise, DSD is planning to install the second CHP generation system of a capacity of some 700kW in one of its STWs.

3. Food Waste and Sewage Sludge (FS) Co-digestion

Currently, landfills are the ultimate disposal points of solid waste in Hong Kong. Without landfill expansion nor measures to drastically reduce the amount of solid waste, the capacity of the three existing landfills will be exhausted one by one by 2019[1] the latest.

The average daily quantity of food waste being disposed in Hong Kong in 2012 was 3,337 tons[2], which accounts for 24.1% of its solid waste. Food waste, by virtue of its higher organic contents, has a higher specific energy value than municipal sewage solids. In fact, the average methane gas production rate of food digestion is usually much higher than that of municipal sewage sludge.

In view of the high energy value of food waste, it is considered that if all the food waste is delivered to the sludge treatment facilities in STWs for co-digestion with sewage sludge to generate biogas, the amount of energy recovery can be remarkably enhanced and the demand for landfills can be reduced. Figure 3 shows the co-digestion workflow.

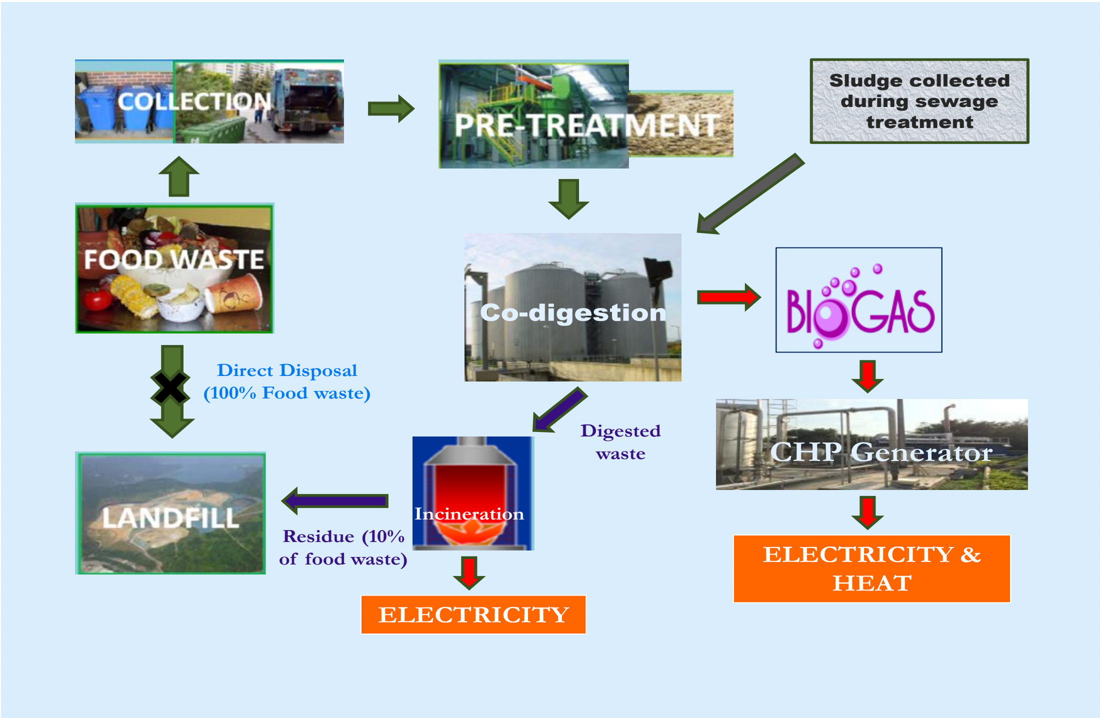

Figure 3: Co-digestion of Food Waste with Sewage Sludge

Though FS co-digestion is a fairly well established technology which has been practised overseas, there is a lack of reference in the application of the technology in Hong Kong. As such, a bench-scale laboratory test on anaerobic co-digestion of food waste with sewage sludge is being conducted to ascertain the feasibility and performance of the technology at different operating conditions, including (1) different solid retention time, (2) different sewage sludge salinity (Note: some sludge in Hong Kong is salty given that seawater is used for toilet flushing in many areas), (3) different food waste/sludge ratio, and (4) different types of food waste. Sewage sludge samples are collected from two secondary STWs while food waste samples are prepared based on the generic food waste composi-

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[1] The Hong Kong SAR Government: Discussion Paper for the Legislative Council Panel on Environmental Affairs at 24 Feb 2014

[2] The Hong Kong SAR Government: Monitoring of Solid Waste in Hong Kong - Waste Statistics for 2012

tion in Hong Kong. The solid content of feed sludge of co-digestion is controlled at 2% to 3% and the default co-digestion temperature is 35°C. It is expected that the results will provide essential information for taking further steps towards FS co-digestion, including an associated pilot plant trial.

The pilot plant trial will be conducted in one of DSD's secondary STWs with anaerobic digestion facilities to determine the feasibility, technical requirements and performance of co-digestion (e.g. extent of reduction and dewatering of sludge as well as productivity of biogas). It is hoped that this can lead to a longer-term implementation plan for territory-wide application of co-digestion of food waste with sewage sludge, and therefore bring about the benefits of better utilization of renewable energy, reduction of greenhouse gas emission and reduction of the demand for landfills.

4. Photovoltaic (PV) Technologies

Over the years, DSD has endeavored to make full use of the open space in its STWs and pumping stations to capture solar energy for subsequent use as far as practicable.

Accordingly, DSD has installed various large-scale standalone and grid-connected PV systems for supplying electricity to equipment at its various major facilities. The total capacity and annual electricity output of the PV panels were about 114 kW and 104,000 kWh per year respectively in 2014.

Besides, DSD has installed hybrid lamp posts, each equipped with a solar panel and a mini wind turbine, to capture both solar and wind energy in its STWs and pumping stations since 2011. Currently, the total capacity is about 49 kW.

Given the lack of available open space for PV panel installation coupled with competing uses of space such as equipment installation in DSD's plants, space is always a constraint which limits large scale implementation of PV panels. Furthermore, possible glare caused by PV panels to neighboring community, remoteness of PV panels from electricity loads and their susceptibility to physical damage are amongst the constraints that have to be coped with.

At present, most of DSD's PV systems are installed at the roofs of its sewage treatment facilities and pumping stations. In order to identify more flexible locations for installation of PV systems and to save limited flat spaces for other uses, DSD is carrying out a pilot study on the use of vertical type Building Integrated Photovoltaic (BIPV) system. Accordingly, a vertical type BIPV system is being installed at one of DSD's STWs to investigate the system's performance and efficiency with different solar cell materials (i.e. Mono-crystallite silicon, Poly-crystalline silicon and Amorphous silicon). It is anticipated that the proposed vertical type BIPV system will not only allow better space utilization, but will also bring about an annual saving of some 1,750 kWh in electricity. This pilot study will provide useful reference for any future installation of such system in DSD's various facilities.

Furthermore, a PV system using poly-crystalline silicon will be installed at Siu Ho Wan Sewage Treatment Works in phases in 2015 and 2016. The design total output power is more than 850 kW peak, with a proposed expansion to 1,100kW peak. When fully commissioned, it would be the largest PV panel installation of the government as well as the largest in Hong Kong.

5. Conclusions

Population growth, economic development and rising public aspiration for better quality of life and sustainable development have raised the demand for an environmentally friendly and energy efficient sewage treatment systems in Hong Kong.

Biogas from sewage sludge, which used to be considered as waste, and solar radiation are major sources of renewable energy that can be found in DSD's sewage treatment facilities during the day-to-day operation. The use of CHP plants, being fast-growing installations in DSD, is considered to be one of the most practical and effective means for turning biogas into useful energy. While a study is underway to install the 6th CHP system in DSD's STWs to optimize biogas utilization, other studies are being carried out to boost biogas generation from sewage sludge by adopting new technologies/processes. The new technologies/processes include anaerobic digestion of chemically enhanced primary treatment sludge and ultrasonic pre-treatment of sludge to enhance anaerobic sludge digestion. Besides, the feasibility of employment of biogas-fuelled cells to utilize biogas to co-generate electricity and heat is also being examined through laboratory tests. Separately, the operating requirements and performance of FS co-digestion, which can turn food waste into useful energy, increase the yield of biogas and reduce the burden of landfills, are being studied in the context of Hong Kong’s environment.

To further promote the use of solar energy, the largest PV system in Hong Kong is planned to be constructed in one of DSD’s STWs.

DSD will continue to keep abreast of the latest development in energy saving technologies and renewable energy utilization, and to strive to reduce energy consumption as well as greenhouse gas emission in the course of its operation. It is envisaged that new technologies that will emerge in the not too far distant future will help further enhance the performance of the systems that utilize renewable energy, whereby providing even more contributions to sustainable development.

References

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