Power Generation and Heat Recovery
Case Study: A Synergy Project between a Waste Water Treatment Plant and a Green Waste Composting Platform

C. Jeuch-Trommsdorff*, A. Benz*, R. Moser*, A. Ulli**

* Hunziker Betatech AG, Bellariastrasse 7, 8002 Zürich, Switzerland
(E-mail: *corinne.trommsdorff@hunziker-betatech.ch)*
** Axpo Kompogas AG, Flugplatzstrasse 5, 8404 Winterthur, Switzerland

Abstract
A common valorization of digester gas and composting gas increases the efficiency of the co-generator installation by 10% to 15%. In this case study, a green waste fermentation and composting platform and its neighboring waste water treatment plant (WWTP) opted for a common co-generator: about 600,000 m^3 of digester gas and 1,900,000 m^3/year of fermentation gas (biogas) transformed into electricity and heat. The energy content of this combined gas source is about 13,800 MW/a, out of which about 38% is transformed into electricity, about 42% is converted into heat, and 20% is lost. The electrical energy produced (600 kW) is sold to the Swiss electrical grid (Swissgrid Program) as *Ökostrom*, or "green power," at a higher price than that of normal power. The heat produced (660 kWh) is used to heat the composter (60 kWh), the digester (125 kWh), and the buildings (25 kW). The excess heat (450 kWh) could also be used for a future low-temperature biosolids drying project, whose life-cycle costs would be counterbalanced by the reduction in disposal costs. This project allows for an optimal use of the energy content of biogas and digester gas. Once drying is implemented, the environmental impact will be even more beneficial with a reduction in transport and the facilitation of phosphorous recovery from dried biosolids. In this case study, the large amount of biogas produced would enable the implementation of low-temperature biosolids drying using the excess heat of the co-gen facilities. The ratio of the biogas to the digester gas production has to be at least 2.5 to 3.0 in order to produce sufficient excess heat for a low-temperature dryer. Low-temperature drying is the most ecological and sensible way of using locally produced waste-heat all year long.

Keywords
Digester gas, biogas, co-generator, biosolids drying, biosolids digestion, co-digestion, heat, energy

INTRODUCTION

Most WWTPs produce digester gas, which they use for digester and building heating. In Switzerland most plants of more than 20,000 equivalent inhabitants also have a co-generation facility that meets part of their power demand. The efficiency of modern co-generation facilities varies between 24% and 38% for capacities between 0 kW and 250 kW, above which the efficiency plateaus at 38% (see Figure 1). It is therefore advantageous to consolidate that valorization of gas into one common co-generation facility.

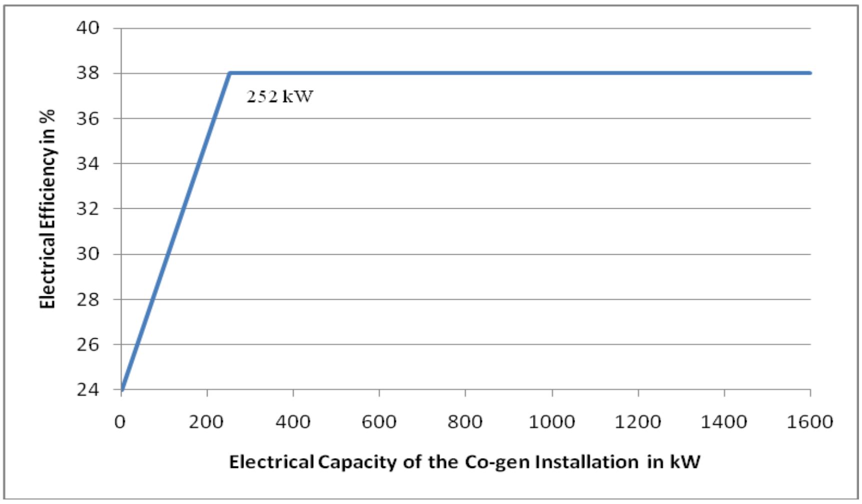

Figure 1. Minimum electrical efficiency requirements for co-generation facilities at WWTPs to be eligible for the CRF Program (Cost-covering Remuneration for Feed-in to the electrical grid). Swiss Energy Ordinance (2010).

The WWTP of Falkenstein in Oensingen, Solothurn, Switzerland has a capacity to serve 30,000 equivalent inhabitants. Its biosolids-handling facility treats 50,000 equivalent inhabitants thanks to direct deliveries of food industry solids. The high concentrations of the food industry solids boost the digestion process and allow for a particularly high gas-production ratio. A green waste composting platform with a bioreactor producing methane gas was built next to the WWTP in 2009.

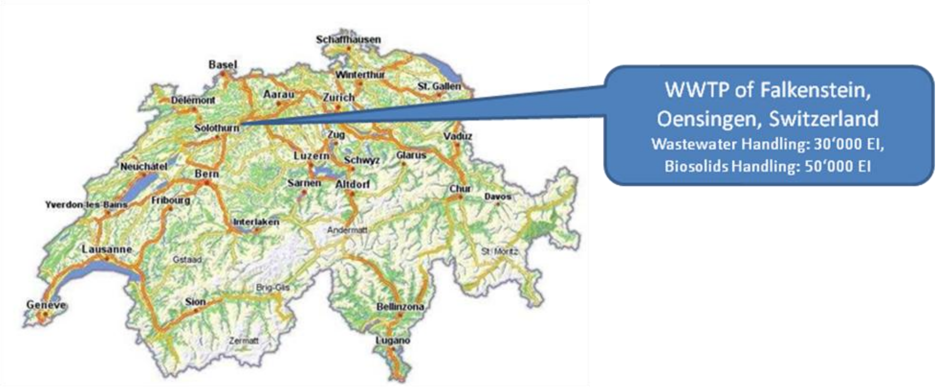
WWTP of Falkenstein, Oensingen, Switzerland
Wastewater Handling: 30'000 EI,
Biosolids Handling: 50'000 EI

Figure 2. Geographic situation of the WWTP of Falkenstein, Oensingen, Switzerland

This presented an opportunity for a common valorization of digester gas and fermentation gas and for a higher efficiency co-generation facility. Methane gas from the two facilities is burned in a co-generator. The power produced is sold to the Swiss electrical grid as “green power.” The heat produced is used to heat the fermenter, the digester, and the buildings. The excess heat could also be used for a low-temperature biosolids dryer.

A positive outcome of this synergy between the WWTP and the fermentation and composting platform is the possibility to use most of the heat produced by the processing of biogas in the co-gen facility (see Figure 3).

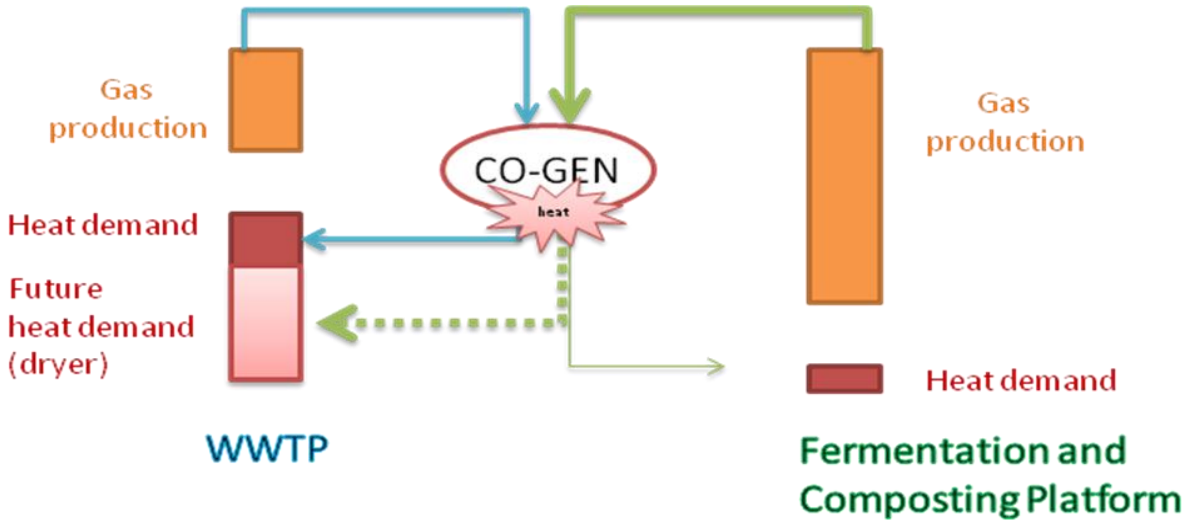

Figure 3. Synergy between a WWTP and a green waste fermentation and composting platform.

CASE STUDY: USING BIOGAS FROM GREEN WASTE COMPOSTING AND DIGESTER GAS

Power Production

About 600,000 m^3 of digester gas with a 62% methane content are produced yearly in the WWTP. The composting platform produces about 1,900,000 m^3/year with a 55% methane content. The energy content of this combined gas source is about 13,800 MW/a (@ 10 kW/m^3 of methane gas), out of which about 38% is transformed into electricity, about 42% is converted into heat, and 20% is lost. The co-generator efficiency is about 10% higher than that of the smaller engine, which would have been installed at the WWTP without this project. The common valorization of digester gas and fermentation gas allows for increasing the efficiency of the power production.

The co-generator is owned and operated by the composting facility. The installation has a capacity of about 600 kW (5.2 million kW/a), which is sold to the Swiss electrical grid (Swissgrid Program) as *Ökostrom*, or "green power." Green power is sold to Swissgrid at a higher price than that of normal power, which effectively results in a subvention for the power production facility.

A contractual relationship regulates the gas and heat exchange between the composting facility and the WWTP. Digester gas from the WWTP is sold to the fermenting facility for the value of the equivalent power sold to Swissgrid (0.237 CHF/kWel). The heat is bought back at 0.02 CHF/kWth for a base quantity, and then 0.01 CHF/kWth for additional heat.

Heat Recovery for Heating and a Future Biosolids Drying Project

The heat from the co-generator engine is directed to two heat exchangers, which heat the hot water loops of the WWTP and of the fermenting facility to 90ºC and 88ºC, respectively. The heat is then distributed within the facility, either directly from the hot water loop or from a heat reservoir, where it is stored for future distribution. The heat reservoir serves to buffer the difference between the heat production rate and the heat requirements for digester and building heating.

Operational Challenges

A few challenges of this gas and heat exchange are still being worked out in this early stage of the project (one year in operation): 1) the temperature level of the hot water loop, 2) the gas production variations, and 3) the winter low-production/high-heat demand scenario.

The temperature level is the main operational challenge and is very project-specific. The digester heating system uses a batch process, which was dimensioned with a hot water loop temperature of 88ºC to 90ºC prior to the co-gen project. This high temperature can be achieved only when the co-generator runs at 100% capacity. At other times the loop temperature is lower, which results in an increased batch heating time. This problem can be resolved through optimization of the co-generator run times as well as of the biosolids heating system. As an option, a pre-heating heat exchanger could be installed to take advantage of the lower temperature return flows.

The ongoing optimization of gas storage and co-generator run times is a normal procedure after a project start-up. It will result in improved electricity production efficiency and higher hot water loop temperature.

The winter scenario is not a detrimental issue because the heat balance is strongly skewed toward excess heat production (see Figure 4). The co-generator produces, on average, 660 kWh of available heat. The facility's average heat requirements are as follows: composting facility (60 kWh), digester (125 kWh), and WWTP building (25 kW). These result in about 450 kWh of unused heat. This skewed heat balance can potentially be used to dry biosolids, and a new design project has been proposed to take advantage of this positive imbalance.

Low-Temperature Biosolids Drying

The WWTP annually produces about 1,200 dry tons of biosolids that are currently being transported to another facility for dewatering and incineration. A biosolids drying project would involve installing a dewatering facility and a biosolids dryer that would enable dried biosolids to be transported directly to the incineration facility (the use of biosolids in composts, as well as in agriculture in general, is no longer allowed in Switzerland). The heat requirements of the dryer project would be about 250 kWh, using a low-temperature belt dryer with a 24/7 operation schedule. The seasonal heat variations have been accounted for. As shown in Figure 4, the heat demand can be met during all seasons. The implementation of waste heat recovery from the dryer waste flows would allow for the operational flexibility required in biosolids handling and would minimize the need for storage. With this dryer project, about 60% to 80% of the available heat would be used, depending on the season. This could possibly lead to the drying of biosolids from neighboring plants in order to increase the profitability of the project.

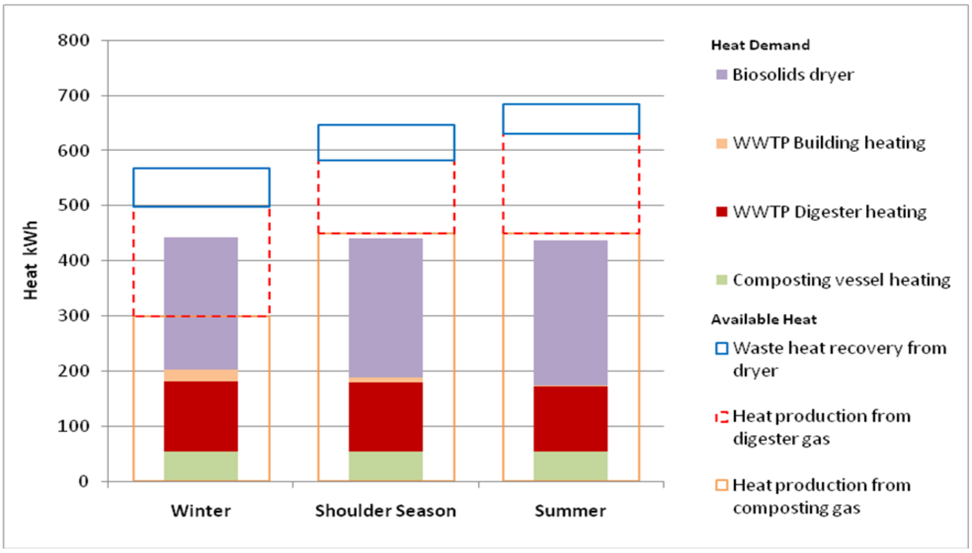

Figure 4. Comparison of the heat demand and the available heat.

Economics

The cost of buying and installing two co-generators, one for each facility, was comparable to that of buying one common bigger machine and building the necessary interfacility coordination infrastructure.

The cost of the dryer project is slightly higher than that of the current liquid (10% TS) biosolids disposal. If the dryer were built 30% to 50% larger in order to process biosolids from neighboring facilities, the dry biosolids disposal costs would become lower than the current costs. However, using 90% to 95% of the available heat implies a loss in operational flexibility and the need for a large biosolids storage, with its associated odor problems during storage and subsequent drying.

Environmental Impact

With the common valorization of gas, the energy from the digester gas is entirely used (no waste) and efficiently used (38% efficiency of the co-gen), thus reducing the carbon footprint of the facility.

With the proposed dryer project, the carbon footprint of the WWTP would be further reduced in two ways: 1) the transport requirements would be significantly reduced as a result of the small volume of dried biosolids in comparison with 10% TS biosolids; and 2) the locally produced heat would no longer be dissipated, but rather would be used to dry the biosolids prior to incineration: the burning value of dried biosolids is +36 kW/EQ,a, instead of -1.4 kW/EQ,a, for 30% dewatered biosolids, excluding transport energy (Müller et al., 2009).

In addition, the drying of biosolids could open up the possibility of recovering phosphorus, which is a finite resource. The phosphoric content of biosolids is currently being diluted in the incineration ashes, as biosolids are burned in common facilities with other wastes. Mono-incineration facilities burning dried biosolids are currently being investigated in Switzerland as a means to recover the resource phosphorus from the ashes of biosolids.

SPECIFICITIES OF THE PROJECT AND APPLICABILITY TO OTHER PLANTS

Project Specificities

A few specificities facilitated the Falkenstein Project:
- The Swissgrid program for the remuneration of green power production
- Existing facilities
- The gas production ratio between the two neighboring facilities

The Swissgrid Program

The co-generation capital and operational costs are high for small facilities. However, thanks to the Swiss federal subvention program "Cost-covering Remuneration for Feed-in to the electrical grid" (CRF), the small projects also become economical. This program remunerates the power production of co-gen facilities based on a formula inversely proportional to the production capacity of each facility:

Remuneration for co-generation facilities at WWTPs in CHF/kWh = $0.55431 \times A^{-0.2046}$, where A is the capacity of the installation in kW. The maximum remuneration is 0.24 CHF/kWh. Swiss Energy Ordinance (2010).

Existing Facilities

The WWTP Falkenstein has an existing unused building that could host the new dryer, therefore reducing the project costs.

Ratio of Digester Gas to Biogas

For the WWTP Falkenstein, the ratio of digester gas to biogas is about one-third. With this amount of gas, and with the low heat demand of the fermentation process, the heat balance allows for a biosolids dryer project, leaving about 30% unused waste-heat.

Applicability to Other WWTPs

Other WWTPs could benefit from similar synergies. The applicability of this case study is such that the following constraints and boundary conditions should be studied: 1) the amount of gas available in the neighboring facility has to be about two and half to three times the amount of digester gas; 2) the use of more than 70% of the available heat implies a loss in operational flexibility to accommodate the daily fluctuations of the different processes involved: digestion, solids drying, composting, gas processing in the co-gen; 3) the costs of the project will depend on the existing infrastructure, the subventions for power production, and the existing and future biosolids disposal costs; and 4) last but not least, the coordination between two independent facilities can be challenging: it requires precise contractual terms and good working relationships.

CONCLUSIONS

The project in Falkenstein is a win-win situation for the WWTP and the composting platform: the gas is more efficiently used and the larger co-generator has lower operational costs. Consolidating gas sources to operate a common power production facility allows for capital and operational savings. In addition, if ratio of biogas to digester gas amounts to about 2.5 to 3.0, the heat produced, rather than being wasted, can be used for low-temperature biosolids drying.

References

Swiss Energy Ordinance (2010). Ziff. 5.2. and 5.4, Appendix 1.5, revised on January 1. 2010

Müller, Schröder, Schmelz (2009). Massnahmen zur Effizienzsteigerung der Klärschlammbehandlung und –entsorgung (Measures to increase the efficiency of Biosolids Management and Disposal). *Korrespondenz Abwasser, Abfall,* 2009 (56) Nr. 10, 1027-1035.