CO_2 reduction potential of renewable energy generation at water utilities

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1 Introduction

Acquisition, treatment and distribution of water and wastewater require energy. Conversely, water can also contain kinetic or thermal energy (Siddiqi, et al., 2011). There is a strong relationship between water and energy usage, and the magnitude of energy consumption correlates strongly with water consumption rates (Li, et al., 2013). For instance, wastewater can be a valuable source of energy, but wastewater treatment is also one of the largest energy consumers in the water sector (Frijns, et al., 2011). Therefore, it is useful to consider utilizing the energy content of wastewater at water utilities to provide for own electricity and space heating needs (Latvala, 2009). Simultaneously, this will also lead to the reduction of CO_2 emissions.

2 Objectives of the research

The aim of this study is to estimate the energy content of wastewater sludge at Kemin Vesi Oy, and the CO_2 emission reduction potential of using anaerobic digestion for energy recovery.

3 Assessing potential methane yield and energy production

Wastewater sludge has a certain methane production potential. In this study, the value of 150 m^3_{CH4}/tVS is used (Latvala, 2009). As the potential energy production parameter for methane is expressed as cubic meters of methane per tons of organic matter, the amount of organic matter is essential to define by multiplying the annual amount of sludge with organic matter content of the dried sludge. The amount of produced methane during one year was assessed by using equation (1)

$$\textit{Methane production} = \textit{sludge production} * \textit{VS - \%} * \textit{production potential} \quad (1)$$

Where
- Methane production is the amount of produced methane in one year [m^3_{CH4}/a].
- Sludge production is the amount of sludge produced in one year [tonnes/a].
- VS - % is the organic solid matter content [%].
- Production potential is the potential amount of produced methane from one tonne of organic dry matter [m^3_{CH4}/tVS].

As equation (1) gives the output as methane production rate, the amount of energy potential is assessed by multiplying methane production with the specific energy content of methane. Used value for specific energy content for methane in this study is 10 kWh/m^3_{CH4} (Rutz, 2012). In addition, in the estimation of the energy output, it is assumed that combined heat and power (CHP) unit having a gas motor is used in order to produce both electricity and thermal energy for the utility's need. Electrical power conversion efficiency (ηel) is set up to 25 % and thermal energy conversion efficiency (ηTH) 45 %, respectively. As the anaerobic digestor requires heat in order to operate adequately, it is assumed that 5 % of the produced thermal energy is used for heating up the process (Rutz, 2012).

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CO_2 reduction is assessed by setting up a zero emission factor for biogas as it is considered a renewable energy source. CO_2 emissions are thus evaluated by assessing the emissions of energy production from biogas. The principle is that a proportion of energy purchased outside the utility could be replaced with CO_2 -free biogas. Different emission factors defined by Motiva, 2013 are used for both electricity and thermal energy (Motiva, 2012).

3.1 Energy production potential in Kemin Vesi Oy

The amount of annually produced sludge at Peurasaari wastewater treatment plant in 2012 was 2 796 tonnes. The dry matter content of the dried sludge was measured to be 26 %, and organic matter content (volatile solids, VS) of dried wastewater sludge was estimated to be 19.5 %. According to data given by Kemin Vesi Oy, the energy production potential as well as electricity and thermal energy outputs were estimated. Results are illustrated in Table 1.

Table 1 *Energy production potential of anaerobic digestion at Kemin Vesi Oy (Mikkonen, 2013).*

Parameter	Value	Unit
Sludge production	2796	t/a
Dry matter content (TS)	26	%
Organic matter content (VS)	19,5	%
Production potential of methane	150	m^3_{CH4}/tVS
Methane production	**81783**	**m^3_{CH4}/a**
Energy content of CH_4	10	kWh/m^3_{CH4}
Potential energy production	**817830**	**kWh/a**
Electrical efficiency (η_{el})	25	%
Thermal efficiency (η_{TH})	45	%
Electricity output	**204458**	**kWh**
Thermal energy output	**349622**	**kWh**

According to Kemin Vesi Oy, electricity consumption at Peurasaari wastewater treatment plant in 2012 was 833 299 kWh and thermal energy consumption 775 000 kWh, respectively. Based on the energy production potential estimate, the thermal energy output could satisfy about 45 % of heating needs in the plant. In addition, approximately 25 % of electricity needs could be satisfied by utilizing anaerobic digestion. In order to increase the amount of produced methane, other raw materials could be added into the reactor, such agricultural waste and bio-waste, as these materials often have higher methane production potential values. However, the produced energy could be used in wastewater treatment processes and in space heating. In addition, it could be possible to sell produced electricity to the grid (Mikkonen2013).

3.2 The CO2 reduction potential of anaerobic digestion

Table 2 illustrates the CO_2 emission reduction potential, if anaerobic digestion of wastewater sludge was used and the produced energy was utilized on-site. In 2012, Kemin Vesi Oy was using energy provided by Kemi power plant supplying district heat and electricity. The CO_2 emissions of energy generation at Kemi power plant are included in Table 2. Avoided use of external energy would thus contribute to CO_2 emission reduction if Kemin Vesi Oy would utilize zero CO_2 emission biogas.

Table 2 *CO_2 saving potential in Kemin Vesi Oy based on 2012 data (Mikkonen, 2013).*

Parameter	Value	Unit
Consumption of electricity	833	MWh/a
Consumption of heating	775	MWh/a
Production of electricity	204	MWh/a
Production of heating	350	MWh/a
CO_2 emissions factor for electricity	210	$kgCO_2/MWh$
CO_2 emissions factor for heating	161	$kgCO_2/MWh$
Current CO_2 emissions	**300**	**tCO_2/a**
CO_2 savings	**99**	**tCO_2/a**

As seen from Table 2, CO_2 emissions could be reduced by about one third by applying anaerobic digestion on-site. The utilization of biogas could also contribute to the climate strategy of the municipality of Kemi. Furthermore, the amount of other emissions could be also reduced, such as particle emissions originating from Kemi power plant energy production (Mikkonen, 2013).

4 Conclusions

The aim of this study was to estimate energy potential of wastewater sludge and its CO_2 emission reduction benefits at Kemin Vesi Oy, Peurasaari wastewater treatment plant. Based on the energy estimation and data given by Kemin Vesi Oy, the energy conversion of methane produced by anaerobic digestion in Kemi could satisfy 45 % of the heating and 25 % of electric energy needs in the wastewater treatment plant. In addition, CO_2 savings could be reduced approximately 33 % compared to the situation in 2012, if the produced energy would be utilized on-site.

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