Economical process for power to biogas with use of an ordinary sewage sludge digester

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Future electricity production with more wind and solar power will provide a surplus of electricity during sunny periods in the summer and periods of strong winds during for example autumn, which may result in periods with extremely low electricity prices. An interesting solution is to use this cheap electricity to produce biogas through the power to biogas concept by producing hydrogen through electrolysis and convert the hydrogen gas together with carbon dioxide to methane:

$$4\ H_2 + CO_2 \rightarrow CH_4 + 2\ H_2O$$

METHOD

The idea is that by adding additional hydrogen gas to the sludge digester, a larger part of the carbon dioxide produced in the digester will be converted to methane. The process of transforming power to gas will run intermittently when the electricity prices are low and the supply of hydrogen will be highly sporadic at unregularly intervals. By connecting the electrolysis unit to the digester at a sewage treatment plant for converting hydrogen to methane, the only additional cost is for the electrolysis unit, which reduces the capital cost per operating hour.

That the digestion process has difficulties to cope with large variations in the substrate supply is known. A sudden increase in the amount of applied organic substrate causes rapid growth of the fast-growing hydrolysis and fermentative bacteria, whereas the slow growing methanogens do not have time to respond. This can create a build-up of fatty acids that the methanogens cannot convert to methane quickly enough and eventually leads to inhibition of the methane production. Hydrogen is produced through fatty acid degradation and too high hydrogen concentration may inhibit fatty acid degradation. However, since hydrogen is a substrate for slow-growing methanogens, the process should consume produced hydrogen and manage periods of added hydrogen.

The effect on the anaerobic digesters is not that more gas is produced. Instead more carbon dioxide will be transformed to methane and the produced gas will have higher methane content and the carbon dioxide content is reduced when the electrolysis unit is running and hydrogen gas is inserted to the digester. No increased cost of the digester since the volume of the digester is determined by the retention time and the volume of processed sludge. Adding additional hydrogen gas will therefore not require investment in a larger digester. In contrast, the cost of upgrading is reduced when the methane content increases and the volume sold methane increases resulting in increased revenue.

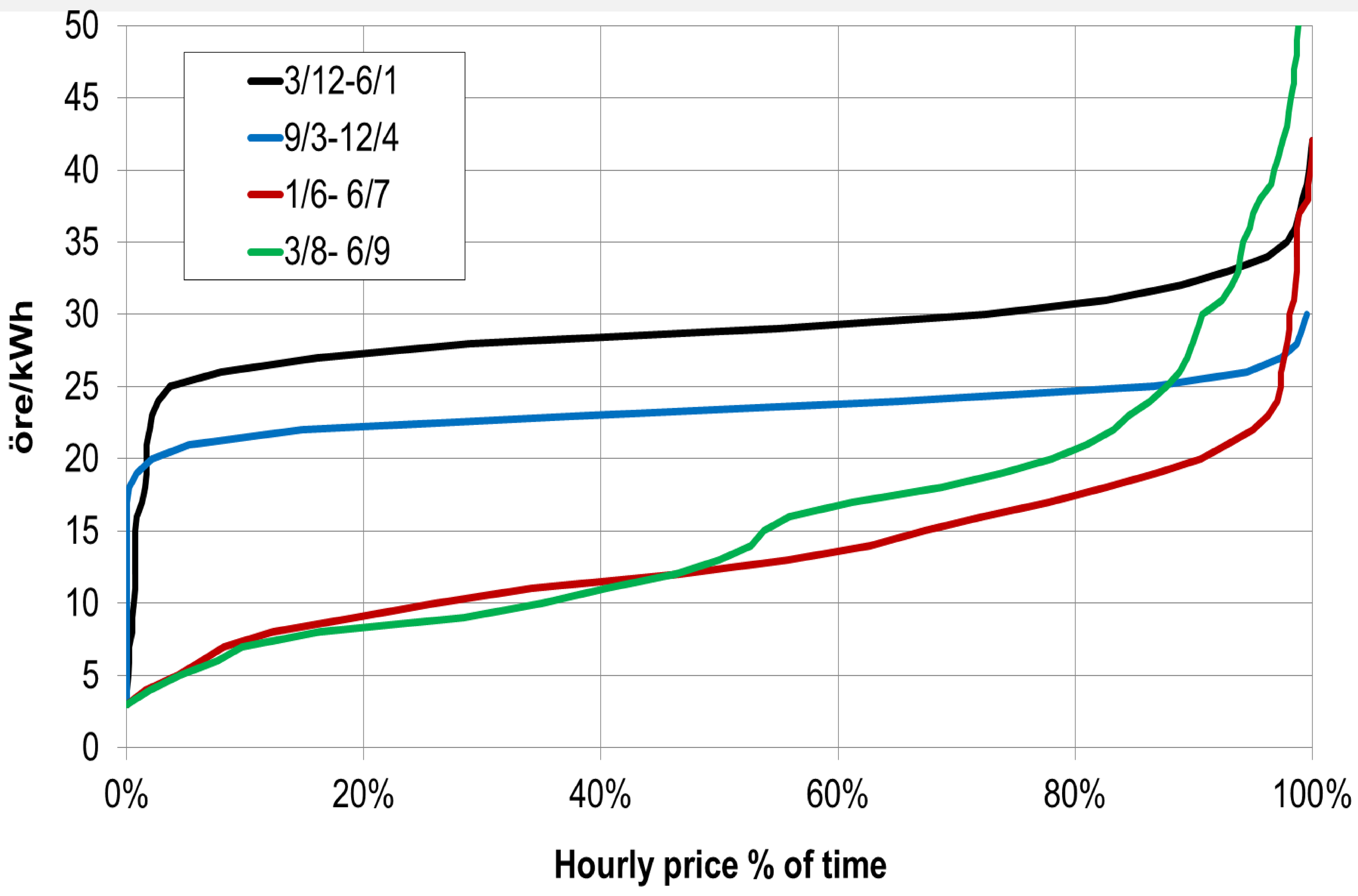

Figure 1 – Variation of electricity price during different periods from December 2014 to 2015. (http://www.vattenfall.se/sv/timpris-pa-elborsen.htm).

RESULTS AND DISCUSSION

Transformation to biogas can be made in a Sabatier reactor or by using methanogens in an anaerobic digester. Location study of power to gas in Sweden using the Sabatier process has been made by [1]. However, using the Sabatier process there will be cost both for the electrolysis unit and for the Sabatier reactor which needs stable reaction conditions and a pure carbon dioxide stream. Successful trials have demonstrated the technology with the conversion of hydrogen to methane by hydrogen input in an anaerobic digester for biogas production [2,3].

Since the equipment only operates when there is cheap electricity, the capital cost of the process prolongs the payback time in comparison to a continuous process. If the electricity price during X % of the operating time is low enough to convert electricity to gas, the capital cost per operating hour becomes 100/X times larger compared to a process that can run continuously. To get a cost advantage the investment and operation cost and the cost of purchased electricity must not exceed the purchase price for the biogas. Figure 1 shows variation of hourly electricity price on the Nordic power exchange Nord Pool Spot for some periods during 2014 to 2015. To this price is the variable network fee, estimated to 0.024 SKR per kWh, and cost for electricity certificate, 0.03 SEK per kWh, added.

Calculation of the profitability has been made based on investment costs, operating costs, revenue from the sold gas and the price of the electricity. An alkaline electrolysis unit with 10 years operation is used there the electrodes that are not used continuously can be used for longer times. The life of the rectifier and other peripherals is estimated to 30 years. It was estimated that 1 kWh electricity is converted to 0.61 kWh biogas and that the income from sold biogas is 0.95 SEK per kWh. The investment cost for electrolysis unit was estimated to 6 000 SEK per kW.

The calculation shows that it can be profitably if the hourly price of electricity during the whole year is below 0.45 SEK, or if the price is below 0.39 SEK for 50% of the year or below 0.31 SEK 30% of the year. However, this calculation is the base for deciding about making the investment. When the investment have been made running the electrolysis unit will be based only on the operational cost. Running the electrolysis unit whenever the electricity prize is lower than the gas price times 0.61 (conversion losses) minus the operational cost will contribute to pay back the investment.

CONCLUSIONS

Preliminary estimations shows that conversion of power to biogas with electrolysis and addition of hydrogen gas to an ordinary anaerobic sludge digester can be an economical solution.

References:

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