BIOGAS FARMING

An energy self-sufficient farm in Finland

Energy self-sufficient farms which also provide energy income in all energy use categories - electricity, heat, automotive fuel and machine fuel - fulfil many targets of the European Union agricultural, energy and traffic policies. Despite EU policy support, Kalmari farm in the village of Leppävesi, 15 km from city of Jyväskylä in Central Finland is a very rare case of such a farm scale polygeneration facility. The biogas production system is a result of an individual farmer's vision and efforts in the face of the Finnish political environment that, instead of granting support, maintains many barriers to such activities. Ari Lampinen, University of Jyväskylä, Finland describes the system.

Contact:
Ari Lampinen, Renewable Energy Education and Research Programme, University of Jyväskylä, Finland, e-mail: ala@jyu.fi

Erkki Kalmari's farm is an old family farm where a self-designed and self-constructed biogas reactor system has been in operation since 1998, originally producing electricity, heat and fertilizers, and since 2002 engine fuel as well. The mesophilic anaerobic fermentation reactor co-digests cow manure, food industry waste, kitchen waste and plant waste. The farm is currently self-sufficient in electricity, heat and automotive fuel and is generating extra income by selling electricity to the grid. Automotive fuel sales are scheduled to commence in 2005.

The biogas system overview is shown in the Figures 1 and 2. The main feedstock for the reactor originates from 40 cows and 60 calves in an open cow house (A) where the animals are not tied but free to move around. The raw sludge is stored in a closed intermediate storage (B) facility. Biowaste storage building (C) contains waste from the local food industry (sweet factory), kitchen waste from the farm and plant waste from the farm. Cow sludge and biowaste are mixed in a 90 m^3 mixer tank (D). The mixer tank is behind the biowaste storage building but is not visible in the aerial photo. The raw mixed sludge is pumped into a 150 m^3 biogas reactor (E). The reactor is kept at a constant temperature of about 35°C that is optimal for mesophilic bacteria catalysing the anaerobic digestion process that produces biogas and fermentation residue. The reactor also acts as intermediate biogas storage. Process control and monitoring electronics as well as CHP unit and gas boiler are located in building (F) where the produced raw biogas is pumped. Hydrogen sulphide is removed from the gas biologically inside the reactor and water by absorption immediately after the reactor. The resulting gas contains about 60-65% methane and 35-40% carbon dioxide. For automotive

Figure 1: The Kalmari farm biogas reactor system in Leppävesi, near Jyväskylä in Finland. (Lauri Jokela)

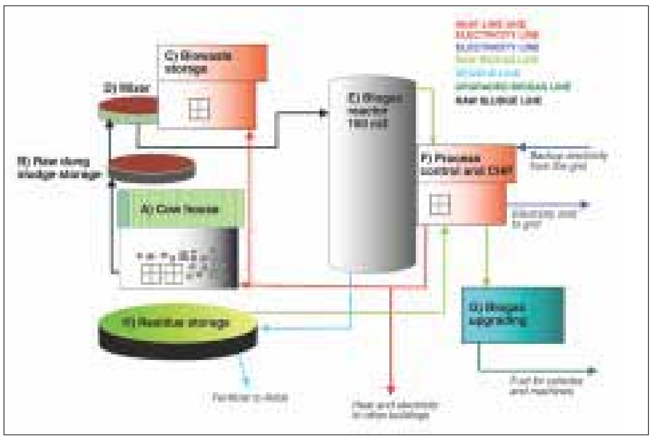

Figure 2: Components of the Kalmari biogas system. (Jari Jokela, Jukka Noponen, Ari Lampinen)

fuel use the biogas is upgraded by water scrubbing in a container (G) to 200 bar 98% methane.

The hydraulic retention time (the average feedstock processing time) is about 20 days, after which the fermentation residue is pumped into a 1500 m^3 covered residue storage tank (H). It also acts as biogas storage and a post-fermentation reactor where about 6% of the biogas is produced during an average storage time of 3 months.

Micro-CHP system

The micro-CHP engine used in the farm for power and heat production is a Finnish Sisu Diesel-based, factory-converted Otto cycle fuel oil engine that was optimized for raw biogas at the farm. Such Diesel engines are most commonly used in Valtra tractors. It has 30 kWe electric power capacity and additional 60 kWt heat production capacity. In addition, a separate 80 kWt gas boiler is in use. The raw biogas where hydrogen sulphide and water has been removed can be used directly in the CHP unit and the gas boiler. Carbon dioxide removal is not needed. Electricity is used in the farm and especially during winter also sold to the grid. About 40 MWhe is produced annually. In wintertime, the production level is optimised by storing food industry waste for peak domestic needs and peak grid power price. In summertime, electricity prices are too low to allow profitable sales but selling to the grid replaces flaming when production exceeds consumption. About 250 MWht of heat is produced annually by the CHP unit and the gas boiler. It is used for hot water heating, space heating and crop drying (Figure 3).

Automotive fuel sales are due to commence in 2005

Automotive and machine fuel production

For vehicle fuel use the carbon dioxide content of the gas is reduced by water scrubbing from 35% to 2% and the gas is pressurised to 200 bars using a self-designed farm scale biogas upgrading unit. The upgraded biogas - that has higher methane content than the upgraded natural gas in the national pipeline - has been used in a Volvo V70 Bifuel vehicle since November 2002 for over 50,000 km. Annual automotive fuel production is 24 MWh but a substantial increase is possible. Automotive fuel sales are expected to begin next year. Machine use in tractors is also possible and awaits a production decision at Valtra tractor factory that is located 50 km from Jyväskylä. Their tractor engine has already been adapted for biogas as the farm's CHP unit.

The biogas upgrading unit, CHP unit, control and monitoring technology and the reactor itself have been commercialized by Metener Ltd. - a company established by Erkki Kalmari and two University of Jyväskylä staff members allowing turn-key deliveries of complete biogas systems. The most important achievement is the farm scale upgrading unit that had not been commercially available anywhere before. The delivery of the first commercial unit will take place this year (Figure 4).

Performance and economics

The Kalmari farm is the only farm in Finland that produces automotive fuel and one of the very few farms in Finland producing electricity from its own energy resources. Thus, it has been of great interest to environmental technology and renewable energy researchers at University of Jyväskylä and the farm reactor system has been and is a demonstration facility in many research projects. For example it has been used in the EU 6th research framework programme, related to the optimization of co-digestion with various waste substrates and energy crops, enhanced methane production by post-fermentation and by mesophilic to thermophilic conversion, automotive biofuels, climate change mitigation and other environmental impacts, production of fertilizers and comparison of anaerobic digestion with composting as the treatment method of putrescible waste.

The pathogen content of the fermentation residue has been analysed. Compared to the untreated cow sludge, Coliform bacteria are reduced by over 99% and Faecal streptococci by almost 98%. These contents are lower than the limits required from minced meat for human consumption.

Figure 3:. Micro-CHP system: 30 kWe and 60 kWt. (Jeremias Kalmari)

This has been achieved by a mesophilic process meaning that further reductions are obtainable if the farm moves to a thermophilic process, i.e. from 35ºC to 55ºC. These results also support the argument that a hygienic post-treatment unit would not be necessary in a thermophilic farm biogas reactor.

The main economic benefit comes from offsetting the farm's own energy and fertilizer costs. In addition to energy self-sufficiency in other than tractor use, commercial fertilizer need has decreased by more than 60% due to the improved fertilizing effect of the fermentation residue compared to raw slurry. Electricity sales and industrial waste gate fees provide direct income. Additional income comes from substantially increased milk production resulting from improved cow health due to decreased pathogen cycling. Auxiliary benefits include many environmental effects of which reduced smell could become a major reason for the promotion of farm biogas systems.

The first commercial turn-key delivery of this technology - that took place this year - shows a short payback time of only 5.5 years without subsidies. Because that farm received a 34% government subsidy, the payback time was reduced to below 4 years. Some 50% shorter payback time is possible by self-construction and utilization of recycled components. Because Finnish energy prices are among the lowest in Europe and renewable energy promotion mechanisms are among the weakest in Europe it is likely that in most other countries the payback time would be shorter.

Figure 4: (left) Erkki Kalmari refuelling his vehicle using upgraded biogas. (right) The text on the back of the car says: "Dung is my fuel. Consumption 0.5 m^3 of cow slurry or 50 kg of kitchen waste per 100 km." (Jeremias Kalmari, Jari Jokela)

Impacts on Finnish energy policy

The Finnish political environment is hostile regarding farm scale electricity and engine fuel production. Rural electrification in Finland took place before the Second World War by grass-roots activity of farmers and co-operatives. The Finnish government did not support, and has never supported, such activities in farms either financially or technically. A peculiar national problem is the powerful Finnish agricultural organization MTK that has taken a stand against all other farm energy production except wood for heating-only use. In Finland two economic instruments for renewable energy promotion are in use: an investment subsidy of 1-40% based on subjective civil servant decisions and a small electricity tax credit of 0.25-0.69 cents/kWh. The Kalmari farm was not granted either of those support types.

Figure 5: Demonstrating the biogas car ("biokaasuauto") for Finnish MPs at the Parliament house in Helsinki. No bad smell from the exhaust pipe was detected. Many MPs made test drives around the Parliament house. (Ari Lampinen)

But this practical example has been the main driving force for changing the policy. In 2002 the law on electricity tax was changed by the Parliament as a compensation for granting permission for a 5th Finnish nuclear power plant and biogas based electricity was granted a 0.42 cents/kWh tax credit. However, due to the administrative complexity of getting the tax refund, only large companies have so far been able to benefit from it. Furthermore, farm biogas systems have now been granted a 34% investment subsidy. However, this policy that is completely controlled by the Ministry of Trade and Industry seems to have been reversed this year.

Automotive biofuel use in Finland used to be prevented by huge tax barriers. In the case of Erkki Kalmari's biogas vehicle the annual extra vehicle tax was 11,000 euros. However, this tax was removed at the beginning of 2004. Given the fact that only biogas fuel and vehicles were fully tax exempted, not other biofuels, is an indication that it was the Kalmari case that had driven the law change. Most of the other automotive biofuels are hit by a daily tax of at least 330 euros when used on public roads. However, biogas vehicles have come up against an innovative new barrier invented by the Ministry of Finance: they always have to fulfil the next EU emission norm instead of the current one. It is not likely to become a technical problem because most biogas vehicle emissions are very much lower than those of conventional vehicles. But it creates an administrative barrier since it is in practise difficult to obtain such certificates - especially for used imported vehicles and converted vehicles that form the majority of the world methane vehicle market.

Due to the EU RES-electricity, automotive biofuel and energy taxation directives, all EU countries are moving towards larger scale use of automotive biofuels and RES electricity. Most of the renewable energy resources are owned by farms so it is crucial for the EU targets to be able to get those resources into the market. Increasing energy self-sufficiency in farms is not enough, but energy income should become an important part of agricultural sector income. To make this transition happen many kinds of political measures need to be taken. However, for many individual politicians and other decision makers, targets and directives are not enough for action. They need to see the new technology in practice and successfully use it in their own country. For that reason the Kalmari farm demonstration has EU wide interest. Hopefully many similar demonstrations will be seen in the near future, whether the technology is biogas focused or something else.