BIOGAS FROM GREEN AND PUTRESCIBLE WASTE IN NEW ZEALAND

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Definition of Biogas

What is Biogas? Biogas is often referred to as swamp or landfill gas. It has what many consider to be a pungent odor, and is readily identified as a component in the air surrounding areas where naturally occurring organic decay is happening. Biogas is produced by the decay of organic matter in an environment that contains little to no oxygen. Typically this naturally occurring bacterial decay is underground or in areas where the access to oxygen is limited by gas displacement. Biogas is typically made up of a mixture of gases including methane, sulphurous gases and carbon dioxide.

For clarity - Biofuel is the umbrella term for all fuels derived from organic matter. The two most common biofuels are bioethanol, which is produced by processing starchy or sugar rich crops, and biodiesel, a description for fuels produced from vegetable oils.

Biogas is also a biofuel, and it can either be burnt for the production of electricity and heat, or scrubbed and compressed and used as a vehicle propellant.

Over 70 anaerobic digesters are in operation in Europe converting over 12% of the municipal solid waste to biogas. Most facilities have been operating 5-10 years. Europe has unique economic conditions which make anaerobic digestion very cost effective, such as high tipping fees for wastes and special premium prices paid for the purchase of renewable energy.

It is interesting to note in the recent EU Biomass action plan, this organic fraction currently accounts for around half of all renewable resources in the EU. Biomass currently meets 4% of the EU's energy needs - that is 69 million tonnes of oil equivalent. The end uses the EU has listed are heating, electricity and transport, along with the benefit of significantly reducing green house emissions by 96 million tonnes each year. They aim to double this use of biomass by 2010.

The Biogas process

This paper introduces two processes, the 'Aikan' system and the 'Kompogas' system, both developed in Europe, but which I suggest should be considered as an end process for kitchen and green wastes in some of the larger population bases in NZ. Mention will also be made of the ‘Dicom’ process presently being developed in Perth. These anaerobic digestion systems produce a biogas for conversion to power and heat, as well as resultant compost components.

Both processes take a range of organic material, however the Aikan process appears more robust in its ability to accept biosolids and has been deliberately built to deal with the machine wrecking rocks and skateboards that are a problem with in-coming feedstock.

Both systems take in the organic feedstock and utilise bacteria to ‘eat’ the easily digestible organic substances and turn them into biogas. This process, called “anaerobic digestion”, is a naturally occurring chemical process in the environment. The biogas, which contains methane, is then used as fuel, either in conventional internal combustion engines that power electric generators, or fed through a microgas-turbine, which is more efficient in terms of the heat to electricity ratio that is gained. Both processes produce electricity and recoverable low grade heat so the final combined recoverable yield is the important measure here. Alternatively, the biogas can be purified and compressed for use as vehicle fuel or fed into the natural gas network. This is done by a scrubbing process to remove, amongst other things, carbon dioxide, sulphur compounds and water, and compressing it when it is for use in vehicles. The cost effectiveness of this additional scrubbing and compression is very much dependent on the market price for power and petrochemicals, which is quite unpredictable both at present and in the future.

This is a carbon neutral process.
Carbon dioxide is produced during the natural fermentation of organic material since it is a by-product of the anaerobic process. Both these two commercial processes can be regarded as being “CO_2 – neutral” because there is no net addition of CO_2 to the atmosphere. The breakdown of organic material is a naturally occurring process and the CO_2 produced during this process is naturally reabsorbed by new plant growth during photosynthesis. This process can be contrasted with the burning of carbon-rich fossil fuels, which results in additional CO_2 being released into the atmosphere. The generation of renewable energy from a biogas process can replace energy derived from fossil fuels, which means no new carbon dioxide into the atmosphere.

Both processes need at least 10,000 tonnes a year of organic matter supply for the smallest economically viable module. This limits the potential in New Zealand to the bigger centres of population if the organic supply is based on a domestic collection alone. At a rate of 200kg/person/year this translates to centres with populations above 50,000 people.

Kompogas

Kompogas is a two stage, thermophilic process.
The principles of this technology – producing gas from waste and turning it into electricity - have been applied on farms, piggeries, cattle feedlots etc in Europe since the 1950’s. The first Kompogas plant for solid organic wastes from households commenced in Switzerland in the

early 1990's. Kompogas has gained acceptance throughout the world and there are 25 facilities in operation and a number more in construction and development. They are by far the biggest operator in Europe.

The organic waste is pre-conditioned, shredded and screened by an operator, to particle sizes less than 200mm long, and is finally run past a magnet. It is then sent to a fermenter, which is a large steel or concrete in-vessel system, mixed with warm water and left for a period of approximately 15 to 20 days. The gas generation rate depends on the particular composition of the input, but is generally between 100 and 130 cubic meters of biogas per tonne of input.

Apart from the biogas, a high-grade compost is produced in the process. After the gas production, the de-watered spent organics are placed in aerated indoor windrows, which are turned once a week. After three weeks this compost is moved outdoors to mature. The compost is free from weed seeds and pathogens and can be used as fertiliser. In Switzerland, this compost has been approved for use in organic farming. In Australia the solid compost would be classified as Grade A compost. The surplus water from the process is high in nutrients and is used as a liquid fertiliser in agriculture and horticulture.
Biofilters are used to control odours.

Aikan

The Aikan system, on the other hand, is a much newer process which has been based on biological research carried out by this privately owned company in association with three universities in Denmark. The technical solutions are based upon microbiological processes. This system is a two-phase technology - anaerobic digestion followed by aerobic composting. It is robust and simple and has the ability to treat many waste types.
The waste is treated in batches so it is possible to treat different types of solid waste to optimise treatment. The important difference with the Aikan system is that gas and liquid are moved during this process, not the organic waste.

After the organic waste arrives at the mixing hall it is roughly chopped by an agricultural mixer. The plastic bags containing the organic matter are trommel screened out; although I would suggest that use of a starch bag process could save a great deal of this processing. The organic matter is then chopped and mixed with structural material and thoroughly mixed in the agricultural mixer. It is then moved to the process module in that mixer and unloaded. The process module is similar to a large concrete garage with air and water reticulation. All concrete in this facility has to be acid-proof, and North Sea steel is used because of the corrosive nature of the process. The number of process modules required, each having a capacity of 600 cu metres, can be determined by demand and can be added to as the need for capacity grows. This gives the system flexibility and minimises the initial start-up cost. When the module is full, an airtight door is closed and the hydrolysis process begins. Warm liquid containing anaerobically digested material from the existing biogas plant is added through a system of pipes. The temperature is kept at more than 70 degrees C and the liquid recirculated. Part of the Aikan systems development has been a system which controls the pH

using a buffer tank. The biogas is continuously produced and stored in a separate reactor tank. After the process of drawing off the biogas is complete, the waste mass is drained of percolate and active aeration begins within the same module. The door is kept closed. Composting at this stage is at least 70 degrees Centigrade for an hour to eliminate disease-causing organisms. The compost can then be used for agricultural purposes according to EU legislation. Exhaust air and steam from the compost is cleaned by a bio-filter.
After the composting process is finished the compost is transferred to a storage hall where it is further stabilized, then refined according to the needs of the individual buyer.

Comparison of Kompogas and Aikan systems

	Kompogas	**Aikan**
Products	Biogas giving electricity and heat Compost Liquid compost	Biogas giving electricity and heat Compost
Numbers built	Over 25	2
Processing time	15-20 days in the fermenter 3 weeks composting	3-6 weeks in anaerobic module 3-4 weeks composting
Raw material	Green and putrescible waste Grease trap waste; algae All less than 200mm long	Household, kitchen and green waste Industrial organic residues Dewatered sludge (compost only)
Smallest module	10,000 tonne/yr	10,000 tonne/yr
Number of employees		3 people for 10,000 tonne
Land area	3000m2 (20,000 tonnes)	22 000 m2 for 25,000 tonnes
Processor	In vessel fermenter of steel or concrete, continuous	Concrete reactor modules, batch based

Financial matters

These systems are not viable in Europe without a gate fee for the green and kitchen waste. Currently much organic material in the municipal waste stream is going to landfill and thus paying the landfill fee. The aim here in New Zealand would be to collect organic materials separately, and to pay a lesser fee than for landfilling. Certainly, landfill tax would provide that incentive.

It is difficult to do a direct comparison between New Zealand and Europe as the regulatory, subsidy and waste disposal framework and the population densities are so different. For

instance, putrescible waste is banned from landfill in Europe and a large proportion of Europe has a putrescible waste collection in place now.
The gate fee in Denmark is mid range for the range of gate fees for incineration.

At Zero Waste, we have drawn up a feasibility model for NZ conditions, and although some details are under confidentiality, we believe either of these systems could be successful financially and biologically within NZ.
There is considerable difference in the approach of these two companies. Evergreen Energy, which owns the rights for Kompogas in NZ, is aiming to put capital in and fund construction, and then to consequently benefit from the sales at the other end. Aikan however, is a more conventional model seeking to build and supply technical support for a fee.

Production of vehicle fuel from biogas

In this area the Kompogas system has benefits in that it has a clip-on system available to scrub and compress the gas and so deliver transport compressed natural gas.
This is also possible with the Aikan system, although they have not put this into practice yet.
There is a New Zealand firm called Flotech which is doing some work in this area. They don't appear to build a whole biogas system, but they certainly produce the scrubbing and compression machinery.

Currently in the submission stage from the Ministry of Transport is a discussion paper on the production of fuel from renewable sources. One proposal put forward as part of this plan is to provide for tradeable renewable fuel credits for people producing replacement carbon-neutral fuel. If this comes to pass, it could mean that fuel produced from biogas could be eligible to become a tradeable commodity.

In a report prepared for ECCA (Energy Efficiency and Conservation Authority) by Waste Solutions Ltd in June 2005 which was estimating the potential for fuel from ethanol from putrescible waste comment is made that "total biofuel energy yield produced by anaerobic digestion (ie biogas)is approximately tripled when compared to the energy content of the total recovered fuel ethanol. And the biogas process is energy self sufficient."

Comparison with composting

For simple compost production, home composting and windrow composting are obviously cheaper alternatives to the biogas procedure described above.

The capital cost of the in-vessel compost systems appears to be in the same ball park as some biogas plants and so the comparison centers on on-going operational costs and marketability of the end products. The difficulty here is some reluctance on the part of the biogas companies to itemise capital costs in a new market like New Zealand. The obvious difference is that, in composting you are converting some of the carbon in the compost to carbon dioxide and releasing it; versus converting some of the carbon to methane and then storing it for sale and future release. However, given the marketing problems of compost here and overseas, the variability of product offered of these biogas systems warrants investigation.

Green house gas credits

An interesting differentiation emerges from the Greenhouse Gas Office in New South Wales. The NGAC's (NSW Greenhouse Gas Abatement Certificates) created from a 20,000 tpa Kompogas facility are equivalent to approximately 31,000 tonnes of CO_2 (carbon dioxide) per annum. The NGAC's are defined as the amount of methane (expressed as tonnes of carbon dioxide equivalent) that would not be captured in a landfill but which are captured by this biogas process.

This goes some way towards answering those who query biogas plants in comparison with straight extraction of biogas from landfill. Also, with the development of regional landfills, the transport costs of the organic portion of waste could be offset by positioning more numerous biogas plants at locations close to population centers.

Secondary industry Possibilities

There are obvious benefits in producing and selling the methane gas in some form**.** However, some of the products which may be more difficult to sell are the heat and the carbon dioxide that is a constituent part of the biogas. The carbon dioxide, heat and compost are an ideal mixture to attract an associated greenhouse business, such as tomato growing. This would increase the total area of land required, but would be an ideal association.

Risks and downstream employment and environmental benefits

In costing a development like this the fluctuations in prices of electricity and oil make it difficult to develop a reliable feasibility model and this will probably get worse rather than better. Other possibilities to increase viability include positioning the biogas installation in an area with limited electrical line capacity and in having the capacity to store the gas and sell it on the spot price market in times of high demand.

Another vulnerability is the dependence upon a constant supply of organic material to process. Batch processing, as Aikan operates, must lower this risk a little.

The EU estimates the growth in jobs to be 250-300,000 in the biomass field. In Germany more people work in the waste industry than the IT industry; in the U.S.A., although this is no shock, more people work in waste than in the direct auto industry.
Certainly there must be an environmental gain in removing organic matter from landfills, so acid leachate reduces, and in producing compost as well as the heat and energy products.

Other players

In Perth a new technology is emerging which is at demonstration pilot process stage. The process takes municipal solid waste and separates out the organic fraction before putting it through aerobic, anaerobic and aerobic processes to produce biogas and compost. This Dicom technology is a concurrent sequencing batch system in a closed vessel. This system, like Aikan, has put an emphasis on the biological side of the process. As the plant must accept waste on a daily basis, three identical processing vessels that each require five days for loading, followed by 14 days of biological treatment are planned.

The Processing Sequence

After separation, homogenized and pulverized organic material is loaded into the vessel over a 5-day period. During loading, the material undergoes controlled aeration resulting in biological heat generation.

Once loading is complete, the anaerobic process is established with the addition to the biologically preheated organic mass of carefully regulated anaerobic inoculum. The anaerobic phase is thermophilic (>55^{o}C), and has a duration of 7 days.
When the anaerobic phase is complete, the inoculum is drained and supplied to the next vessel, and the final aerobic conditioning phase is initiated.

The methane-rich biogas created in the anaerobic phase is used to generate electricity to meet plant requirements, and the surplus can be sold into the electricity grid, or used on-site for value adding of the final composted product.
In summary, the bioconversion process comprises:

- 5 days of controlled **aerobic** biological heating, prior to
- A 7 day thermophilic **anaerobic** digestion phase,
- Then 7 days of intensive **aerobic** conditioning, leaving
- 2 days for controlled extraction of compost from the vessel, ready for the next batch.

Overall batch cycle time is 21 days - much faster than the two processes discussed previously. Continuous processing therefore requires three identical bioreactor vessels, operated concurrently, each one week out of phase with the next.
This Dicom process has followed a similar evolutionary path to the Aikan system of emphasis on efficient anaerobic production and concentration on control of the microbial environment.

Conclusion

The secret recipe for the successful introduction of biogas from municipal, or green and putrescible wastes, appears to be

- Regulatory environment giving strong fiscal direction
- Excellent biology, good bacteria populations
- Efficient conversion from gas to electricity and/or fuel
- A continuous high quality feedstock
- A market for all products
- Gate fees for incoming organic matter

To put together a project such as this requires a number of players to cross boundaries between waste minimisation, horticulture, job creation, global warning, and carbon credits. And on another plane, Councils, waste operators, financiers, and siloed thinkers in all of the above areas need to cooperate and collaborate. My question to you is……**who is ready to give it a go?**

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