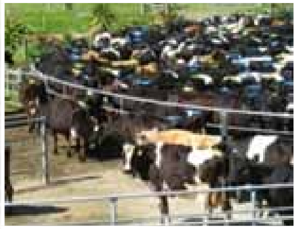
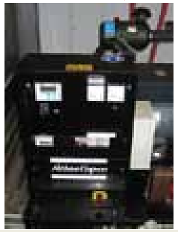
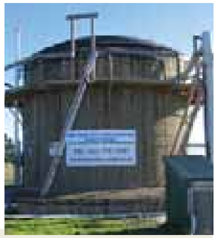
TECHNOLOGICAL PRACTICE CASE STUDY | SEPTEMBER 2009

BIO-PROCESS TECHNOLOGY | YEARS 11-13







COW POWER

In the mid 2000s Christchurch engineer Ian Bywater invented BioGenCool – a process that extracts the biogas (methane and carbon dioxide) from cow effluent using novel biodigester technology. After production it is then cleaned and used as fuel in a co-generation plant to generate electricity. This case study looks at this system and provides extensive curriculum-linked discussion points.

FOCUS POINTS INCLUDE:

Characteristics of Technology
- Transformation of material and energy

Characteristics of technological outcomes
- Physical and functional properties

Technological modeling
- Functional and practical reasoning

Technological products
- Appropriate use of materials to enhance fitness for purpose

Technological systems
- Integration of sub-systems; operational parameters; use of specialist language

SUPPORT MATERIAL

- Natural Systems Ltd: Turning waste problems into energy and environmental solutions
- Curriculum related activites and discussion questions relating to identified focus points are on pages 3 and 4 of this pdf.

COW POWER

In March 2008, The National Business Review *rated Natural Systems Ltd the most exciting environmental technology company in New Zealand. Claire Le Couteur visits the company's founder, Christchurch engineer Ian Bywater FIPENZ, and his energy efficient dairying system.*

Four years ago, Mr Bywater won an international award for his scheme to build an energy efficient dairying system. Since then he has achieved a New Zealand patent for BioGenCool and established a pilot plant on a Landcorp Farming Ltd dairy property in North Canterbury.

The BioGenCool process extracts the biogas (methane gas and carbon dioxide) from cow effluent using novel biodigester technology. After production it is then cleaned and used as fuel in a co-generation plant to generate electricity.

A farmer collecting effluent from 850 cows could save up to $30,000 per year in electricity costs by using BioGenCool. Scale that up, and Mr Bywater reckons New Zealand's four million dairy cows could yield 80 megawatts of power per day.

Effluent to electricity

There are two herds of cows on the 360-hectare Landcorp Farming property; one is milked twice per day and the other herd of older cows is milked only once. The cows generate approximately three cubic metres of manure at each milking and the same amount of digestate flows out of the biodigester in a flow-through system.Effluent from the 900 cows is collected from the concrete pad waiting area outside the milking shed and washed into a central drain using a dilute mixture of liquid manure that gradually thickens. As the last cows enter the shed, fresh water is sprayed from nozzles on the backing gate to clean the pad. Recycling the liquid saves on water use while at the same time keeping the effluent as concentrated as possible for use in the biodigester.

The collected effluent passes into the biodigester – a PVC-lined tank made of tanalised pine and insulated with extruded foam, with a capacity of 160 cubic metres. A 16-kilowatt dual-fuel diesel generator driven by a three-cylinder engine heats hot water and circulates it through piping immersed in the tank, heating the biodigester mixture to 35 degrees Celsius. Bacteria break down the manure in the biodigester, generating biogas, which is 65% methane and 35% carbon dioxide, while a mat of sulphur-digesting bacteria floats on the surface, removing sulphur dioxide from the gas mixture. Heat recovered from the hot oil of the engine when it is running and from the exhaust is put through a heat exchanger to heat the water used to keep the tank's contents active.

Effluent from 900 cows is collected from a concrete pad waiting area…

…and passes into the biodigester.

A small pump operates for about five minutes every hour to mix the contents by removing a portion from the sump level and returning it to the tank through two entry points, one at floor level and one in the headspace. "We wanted to avoid penetrating the tank as much as possible so we used existing injector ports," Mr Bywater explains. "We consider that the hydraulic principle works best, rather than introducing a stirring mechanism into the tank."

When the generator control receives a signal that there is a full headspace of gas, the generator starts up on diesel fuel and synchronises with the grid (mains power). The system then sucks the biogas out of the headspace and switches the generator to dual fuel, running 85% biogas and 15% diesel. The power it generates is fed onto the dairy shed switchboard and then, depending on the local load at the time, it is either used onsite or exported into the network.

"We have exported some power to date," says Mr Bywater. "We export it between milking times when the load is low. When the cows are being milked the electrical load is greater than the generator output so there will be some importing at that time. We always planned to provide about one third of the energy requirement from this particular site and the amount of material that we can get."

The generator uses biogas to generate electricity which is either used onsite or exported into the network.

Colder milk, better fertiliser

As the cows are milked their milk is cooled rapidly by two plate heat exchangers, one inside the milking shed and one outside the building. The second heat exchanger uses ice-cold water from ice slurry made at off-peak times by a machine normally used in the food processing industry and stored in a large tank. The faster the milk is cooled the better its quality, as bacterial counts are lower and the milk foams less. Milk can be kept on the farm for longer at a cooler temperature meaning fewer tanker visits are needed to collect it. This is an added benefit with the present rise in transport fuel costs.

The contents of the biodigester (digestate) flow out into a pit alongside one containing the fresh material, and are used as fertiliser on the farm. Testing shows that it is a more successful fertiliser than the original material and is a healthier, less odorous substance to spread around the farm. It has a neutral pH, compared with the initial effluent which is acidic, and a much reduced pathogen count.

"We constantly have the digestate tested and can see that the N:P:K [nitrogen: phosphorous: potassium] values are unchanged. They are actually stabilised as the material passes through the system and are not lost through leaching or evaporating," says Mr Bywater.

The solid contents of the biodigester flow out into a pit for use as fertiliser.

At the moment all of the digestate is spread on the farm but it could be used on neighbouring farms. Mr Bywater has several ideas on how this product could be used, including processing it to extract the nutrients that cause unwanted enrichment of waterways and making the remainder safe for discharge. This is ideal for areas where the ground is waterlogged for long periods, preventing the spreading of manure slurry onto paddocks.

Mr Bywater is also convinced that the digestate could be used as a food source for farming algae to produce bio-oil. This would replace the mineral diesel presently used in the generator and make the system more independent of fossil fuels. "We have all the raw materials, such as nutrients, sunlight and carbon dioxide, and could use them to grow algae in large plastic tubes or 'photobioreactors'," he says.

The present plant could produce more biogas if more manure was collected. Mr Bywater hopes this will happen if Landcorp decides to build a concrete feed-pad nearby – not only would the animals get better nutrition and produce more milk, they would also leave more of their droppings behind for BioGenCool to process into biogas.

Natural Systems Ltd is looking for investors and people interested in setting up similar systems. There has been strong interest from farmers in Southland who often deal with waterlogged soils and find it hard to dispose of dairy waste. An experienced dairying practitioner in Australia is also keen to find out more and the company has been in contact with the renewable energy centre at Newcastle University in the United Kingdom, which is contemplating installing a biodigester on its farm.

"As far as we know, BioGenCool™ is an unique system" says Mr Bywater. "You can find ice banks in dairies for rapid cooling of milk, although it may not be done automatically, and you will find biogas producing electricity on farms, but to my knowledge no-one has integrated the whole system. We also have a remote monitoring and control system. The dairy farmer has nothing to do. It's all automatic."

Cow Power – Curriculum Links

Detailed consideration of the BioGenCool™ system outlined in this case study can assist understanding of key ideas in the strands of Technology in *The New Zealand Curriculum (2007)*. Here are some focus questions to promote discussion relating to Nature of Technology and Technological Knowledge. There is also a page of Additional resources to help with discussions and to provide further research material.

Nature of Technology Strand

CHARACTERISTICS OF TECHNOLOGY (Explanatory Paper)

- Technology is a purposeful intervention-by-design human activity that results in technological outcomes that impact on the world.
- Technology enhances the capability of humans to transform materials, energy and information.
- Technology uses and produces technological knowledge which is validated in the successful development of a technological outcome.
- Technology is historically positioned and inseparable from social and cultural influences and impacts.
- Contemporary Technological Practice is increasingly collaborative and inter-disciplinary.

Focus Questions

- Discuss the purposeful nature of the development by the examining the potential impact of large-scale adoption of this technology. [Local impacts could relate to the individual farmers and the immediate community; at a national and global level, economic and environmental sustainability issues could be among those considered.
- Material and energy transformation is key to the effective functioning of the BioGenCool™ system. Outline where such transformations are occurring.
- Discuss some of the contemporary economic, social and cultural drivers to the adoption of this technology.

CHARACTERISTICS OF TECHNOLOGICAL OUTCOMES (Explanatory Paper)

- Technological outcomes are material products and systems developed for a specific function through Technological Practice.
- A technological outcome is evaluated in terms of its fitness for purpose.
- Technological outcomes can be described by their physical and functional properties.
- The terms ‘Proper function’, ‘Alternative function’ and ‘Mal-function’ can be related to technological outcomes.

Focus Questions

- List the physical and functional properties of the technological products that link together to form this technological system.
- What measures could be used to determine the fitness for purpose of the BioGenCool™ system?

Technological knowledge Strand

TECHNOLOGICAL MODELLING (Explanatory Paper)

- Technological modelling refers to modelling practices used within technological developments, and includes functional modelling and prototyping.
- Functional modelling allows for the ongoing evaluation of design concepts for yet-to-be-realised technological outcomes.
- Prototyping allows for the evaluation of the fitness for purpose of the technological outcome itself.
- Through technological modelling, evidence is gathered to justify decision making within technological practice.
- Modelling is crucial for the exploration of influences on the development, and for the informed prediction of the possible and probable consequences of the proposed outcome.
- Technological modelling is underpinned by functional and practical reasoning.
- Functional reasoning focuses on ‘how to make it happen’ and ‘how it is happening’.
- Practical reasoning focuses on ‘should we make it happen?’ and ‘should it be happening?’
- Decisions as a result of technological modelling may include the: termination of the development in the short or long term, continuation of the development

Focus Questions

- Outline some of the modelling practices which could have been employed during the development of the system and discuss the functional and practical reasoning which could have underpinned their selection

TECHNOLOGICAL PRODUCTS (Explanatory Paper)

- Technological products are material in nature and exist in the world as a result of human design.
- Understanding the relationship between the properties of materials and their performance capability is essential for understanding and developing technological products.
- Technological knowledge within this component includes the means of evaluating materials to determine appropriate use to enhance the fitness for purpose of technological products.
- It includes understandings of new materials formulation and their potential impacts on future product function.
- The impact of material use and development on product life cycles/ expectancy is also included with regards to understanding material sustainability in its broadest sense.

Focus Questions

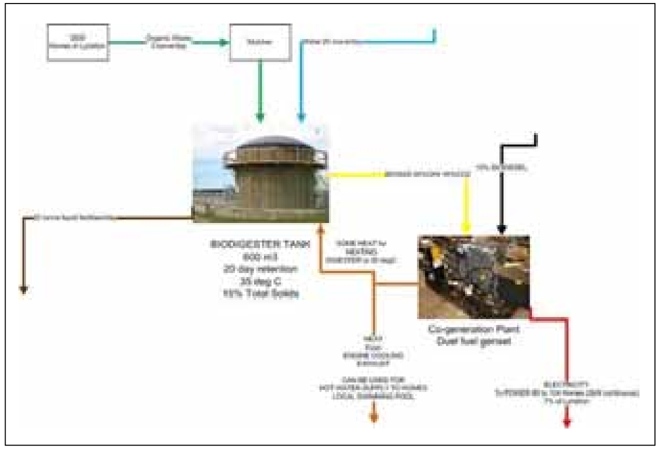
- The importance of the relationship between material properties and their performance capability is reflected in the following statement relating to the choice of wood in the construction of the Biodigestor: “Timber water tanks, chemical tanks, and reservoirs are the only truly sustainable choice for the storage and treatment of water and a wide range of other products.The natural lifecycle cost of a wood tank has minimal impact on the environment when compared to its concrete, steel and plastic alternatives. In fact, the production of dry lumber actually has a negative net carbon emission rating, as wood stores carbon dioxide.” Ref: www.timbertanks.co.nz/ Discus this choice in terms of likely criteria for the evaluation of the overall fitness for purpose of the system.

TECHNOLOGICAL SYSTEMS (EXPLANATORY PAPER)

- Technological systems are a set of interconnected parts (technological products and processes) that serve to transform, store, transport or control materials, energy and/or information.
- These systems exist in the world as the result of human design and function without further human design input.
- Understanding how these parts work together is as important as understanding the nature of the each individual part.
- Technological knowledge, within this component, will include an understanding of input, output, transformation processes, and control.
- Understanding the notion of the 'black box' is included in this component, in terms of understanding, and of developing, complex systems that involve integrated sub-systems.
- This component includes understandings of redundancy and reliability within system design and performance and therefore an increased understanding of the operating parameters of systems.
- Specialised languages provide important representation and communication tools. Understanding these specialised languages is important in system development, maintenance and troubleshooting

Focus Questions

- A schematic of a functional Biodigester system which could utilise organic human waste from homes in the Lyttleton area of Christchurch for the generation of domestic electricity is shown below.



Use this diagram as a starting point to accurately flowsheet the BioGenCool system. This diagram and more detail relating to this process can be found here (Word, 382Kb). A PowerPoint introduction on flowsheeting can be found here (PowerPoint, 2Mb). This process flow diagram can also be used to focus on ideas and terminology used in NCEA Technology achievement standards relating to production and process technology.

LEVEL 2 AS90360

Inform own technological practice through characterisation of an existing production process.

Key terminology used in this standard includes:

Characterisation of an existing production process

- quality control strategies
- sub-setting and/or flow-sheeting
- defining batch, continuous or semi-continuous operating characteristics
- recognising the limitations imposed by legislation, regulations, codes of practice, and societal elements such as religious belief
- key stages
- defining inputs, outputs and yields
- defining purpose of the operation (storage, transport, delay, inspection, or transformation operation with description of the transformation)
- defining levels of key operating variable(s) to be maintained, eg temperature, linear measurement, volume, and
- recognising the nature of the most limiting (bottleneck) aspect of the stage.

In characterising an existing production process students are expected to identify quality parameters for key stages and quality control strategies.

ADDITIONAL RESOURCES

Websites with further material relating to the above focus questions include:

Natural Systems Ltd
Turning waste problems into energy and environmental solutions.
www.naturalsystems.co.nz/News/Entries/2008/8/29_Finding_Power_in_Effluent.html

Biomass and Bioenergy
Bioenergy provides a real alternative to fossil fuels for many applications. New Zealand's geography and climate have placed it at the forefront of countries internationally for the production of food and fibre. This same natural advantage has a prime role in making New Zealand internationally competitive in bioenergy production of many forms.
www.bioenergy.org.nz/bioenergyinfo.asp

Rural Energy
Dairy Industry turning to manure for energy.
www.ruralenergy.co.nz/blog2/archives/2006/03/entry_12.html

Biogas and Landfill Gas
Biogas is a gas produced during the biological breakdown of organic matter which can be used to provide energy. The gas is produced from the decay of vegetation and other organic materials such as animal manures, sewage treatment sludge or food processing waste. This can occur in places where there is little or no oxygen such as in a landfill (where it is known as landfill gas) or under controlled conditions such as an engineered waste digester. Biogas emitted from landfill sites or engineered waste digesters can be used to provide heat or to generate electricity.
www.eeca.govt.nz/renewable-energy/bioenergy/biogas.html

Biogas Systems – New Zealand
Vast quantities of methane (sometimes called bio-gas or "swamp gas") are generated every year by the decomposition of organic material. Methane gas is a near twin of the natural gas that the gas companies and power utilities supply for heating the home, cooking and for commercial/industrial use. Instead of being harnessed like natural gas, however, methane has traditionally been considered as merely a dangerous nuisance that should be disposed of as fast as possible. Only recently a few organisations have begun to regard methane as a potentially revolutionary source of controllable and renewable energy. homepages.ihug.co.nz/~jyotsna/Biogas Systems - New Zealand-Dairy-Power.html