PNCC BIOGAS TO ENERGY PROJECT

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ABSTRACT

This paper describes the process that Palmerston North City Council followed in transforming low rate digesters into high rate digesters and thereby enabling sufficient biogas generation to run a new 716kW Electrical generator. The paper describes the process for determining the requirements of the project, how the cost benefit was derived the generator selection methodology and how the improvements to digester performance were identified and implemented. The performance of the digesters post upgrade are outlined and the process by which the new feed stocks were introduced is discussed.

KEYWORDS

Biogas, Digesters, Trade Waste, Energy Production, Wastewater, Co-Generation

1 INTRODUCTION

This project was developed out of the Palmerston North City Councils original Landfill Gas Project that had been successfully implemented two years previously. That project had raised awareness within the Council the potential benefits of increasing energy production for Councils own use. At around this time the Council had been developing a Sustainable City Strategy of which self-sufficiency in energy production was seen as an important part.

The Water and Wastewater Division of PNCC as part of the overall Sustainable City Strategy adopted its own "Brand" in order to better identify projects related to the strategy. This brand was called "Going Greener", and was linked to PNCC's corporate brand at that time as a way of emphasising Councils ultimate sustainability goal.

Figure 1 PNCC Sustainability Logo

The Going Greener brand covered a series of initiatives with the ultimate aim of PNCC being energy self sufficient for the entire Council operations by 2012. The projects covered by this were; Landfill Gas 1 (the original project), Turitea Mini Hydro increasing existing hydro generation from 120kW to 200kW, WWTP Digester 500kW, landfill Gas 2 500kW, Solar and wind and Energy from Wastes. The Councils target was to generate 100% of electricity needs (2.5MW) by 2012.

There was an existing 1MW Landfill Gas Generator and a 120kW Mini-hydro already in place. However it was assumed that Biogas would replace Landfill Gas as it was forecast to decline over the next 15 to 20 years. Of those initiatives the only ones to be completed were the biogas generation project and the installation of solar panels on the main Council administration building.

The original plan was to locate the new biogas generator alongside the existing Landfill Gas Generator and utilise what was to be surplus landfill gas. The decision was made during the process to utilise only the Biogas from the digesters instead. An analysis of the gas production from the closed Awapuni landfill revealed that this was declining more rapidly than anticipated which meant that there would be insufficient landfill gas to supply a new generator for any reasonable length of time.

It was then decided to focus on Biogas alone and the decision was made to locate the new generator alongside the existing digesters to utilise digester gas alone with possible natural gas supplement.

2 GENERATOR ENGINE SELECTION

Two options of generator ownership were assessed which were for PNCC to purchase the 2nd Combined Heat and Power plant or that the Council enters a partnership type arrangement based on Council supplying sufficient gas for the new generator unit. This was based on the Generator operator owning and maintaining the unit, and then selling the electricity and heat to PNCC (at discount)

A key component in the decision to go ahead with the purchase of the biogas generator was PNCC's ability to increase gas production out of the two existing digesters. It was apparent early on that there was insufficient biogas generation from the existing digesters and that something would have to be done to increase gas production to be able to install and run a generator sustainably.

Extensive financial modelling was undertaken with the assistance of Price Waterhouse Cooper to determine the most appropriate ownership scenario. This resulted in PNCC ownership of a generator as being the most financially favourable outcome. The initial modelling indicated that the pay-back period would be eight years from energy sales alone.

The short payback period and potential for future earnings results from three main factors: sales of produced green electricity, a reduced need to buy pipelined natural gas to supplement the generator and gate fees for receiving new waste materials into its upgraded sludge digester facility.

In total five different scenarios were modelled featuring supplementary gas supplies (natural gas), differing generator sizes and ownership options in order to determine the optimum generator size and maximise the financial return to PNCC.

Three suppliers were shortlisted these being Energen Solutions, Clark Energy and ENTEC Services who were invited to tender for supply of a generator. All parties invited to tender submitted an offer which were all systematically evaluated and Involved extensive reference checks and site visits to evaluate their technology.

The engine that was selected was a MWM (Previously Deutz) TCG 2016 V16 740kW power plant, supplied by Energen of Brisbane. They were the suppliers of the original LFG unit and had extensive experience with stand-alone generation particularly in the mining and oil and gas industries. Energen was selected due to its proven engine management system and gas mixing expertise, (as demonstrated during a site visit at Melbourne Water). The generator offered by Energen had the highest efficiency of all models investigated at 42% overall.

The total cost for the purchase and installation of the new generator was $2.65Million dollars and this included, consultants (electrical and structural design), HV electrical equipment (incl. Transformer and switches) heat transfer pipe work and site works/foundations.

2.1 INCREASING BIOGAS PRODUCTION

Waste Solutions now part of spiire Consultants were engaged to assess the current performance of the Totara RD Wastewater Treatment Plant Anaerobic Digesters. Initial work suggested the baseline biogas potential could be increased to 500kW from existing feed stocks consisting of raw primary sludge. With additional feed stocks biogas production was estimated to further increase supply of up to 750kW electrical production. The original plan was to increase biogas production from the low rate of 1000 – 1500m³/day to 3500 – 4500m³/day.

The reasons for low gas production were thought to be due to incomplete mixing in the digesters. The mixing in the digesters at that time was achieved by sludge recirculation through a heat exchanger 24hrs/day, and gas blowers operated for 8hrs/day through a central eductor tube and pearth lances. A Hydraulic Residence Time (HRT) test was proposed using a Lithium tracer. Mixing time and HRT tests were performed on Digester 1 with the assumption that both digesters would behave identically given their identical design.

It was estimated from the tests that the dual mixing system supplied digester mixing energy within the recommended range (10-20 W. m³ digester working volume) for only 8 hours/day and for the remaining 16 hours/day below the recommended range. This irregular mixing for 16 hours/day was expected to lead to sludge settlement, limited mixing, limited waste/biomass contact and reduced heat supply to the active bacteria. An extension of the operation time for the biogas recirculation blowers was not possible due to noise restrictions during night time as the gas blowers are very noisy.

Results of both the mixing and HRT tests were consistent, and showed that both digesters were well mixed, but only over 55% of the total volume. This meant that almost one half of each digester’s volume was a ‘dead zone’ , with an estimated 25 % of this dead zone filled with stagnant liquor that could take up the lithium tracer but with a low mixing rate and the remaining 25 % filled with settled solids or scum, where no biological reaction took place. The tracer washout rate was consistent with an average hydraulic residence time of 13.2 days at an average combined daily fresh feed flow of 112 m³/day to both digesters. Based on two x 1360m³ volume digesters, the expected digester HRT should have been 24.2 days. Tests showed an available effectively mixed working volume of only 55 % of the design volume (13.2 days/24.2 days) or 750m³ per digester (assuming identical digesters)

2.2 DIGESTER UPGRADES

Once the cause of the current low performance of the digesters had been determined investigations were commenced to determine the most appropriate methods of increasing biogas production, options investigated included cell lysis and pre-thickening.

The final mix of strategies to boost gas production included a clean out of both digesters to restore complete working volume, Installation of improved hydraulic mixing through an external ring main and five injectors, plus the implementation of Booster technology on both digesters. This would allow the addition of high strength/fatty wastes such as dairy factory DAF waste, grease trap waste and piggery waste.

After a clean out of the digesters which confirmed the high volume of inert solids, the first stage of the upgrade program was to install new external hydraulic mixing as a means to increase the available mixing energy in the digesters. The purpose of the external mixing was to introduce a circular motion into the digester which would combine with the existing low volume hydraulic mixing and gas recirculation. This increases the available mixing energy to the sludge and ensures continuous contact with the active bacteria.

The new mixing systems were installed over two years, Digester No.1 was completed in 2009 and Digester No.2 was completed in 2010. The mixing systems consist of a 150mm ring main with five injectors spaced evenly around the circumference of the tank with two 18kW Flygt N series pumps supplying the mixing energy. The external pipes were subsequently wrapped in insulating foam to reduce heat loss.

Photograph 1 and 2 Photo of External Mixing System (left) and Injector (right)

2.2.1 LIQUID WASTE FACILITY TO INTRODUCE HIGH STRENGTH FEEDS

As part of the plan to boost gas production there was a need to introduce new co substrate feed stocks into the digesters as the primary sludge alone was not enough. Modelling undertaken regarding the volumes of new co substrate indicated that at least 60m³ of daily storage was required. In conjunction with Waste Solutions a proposed methodology was developed for introducing new co substrates into the digester and from this a new facility was designed.

The new facility consists of two 30m³ PE tanks with a Rotamix mixing system supplied by Pump Systems of Christchurch fitted inside and connected to a Vaughn chopper pump to re-circulate the wastes. The new waste is drawn in from tankers through a purpose built coarse screen via another Vaughn chopper pump. The delivery process is controlled by PLC and operator panel, the delivery driver can specify both the volumes of waste and its type. This then controls which tank receives the waste and also the make-up volume of existing sludge. This process is summarized in figure 2 and the new facility is shown in photograph 3 below.

Once the new waste is in the tank it is topped up with fresh sludge at a 1:1 ratio and is then mixed for 20 minutes before being pumped over to the digester via a third Vaughn chopper pump. The top up sludge comes from Digester 1 and is used to both improve the handling of the DAF which is quite viscous and to seed Digester 2 with primary sludge.

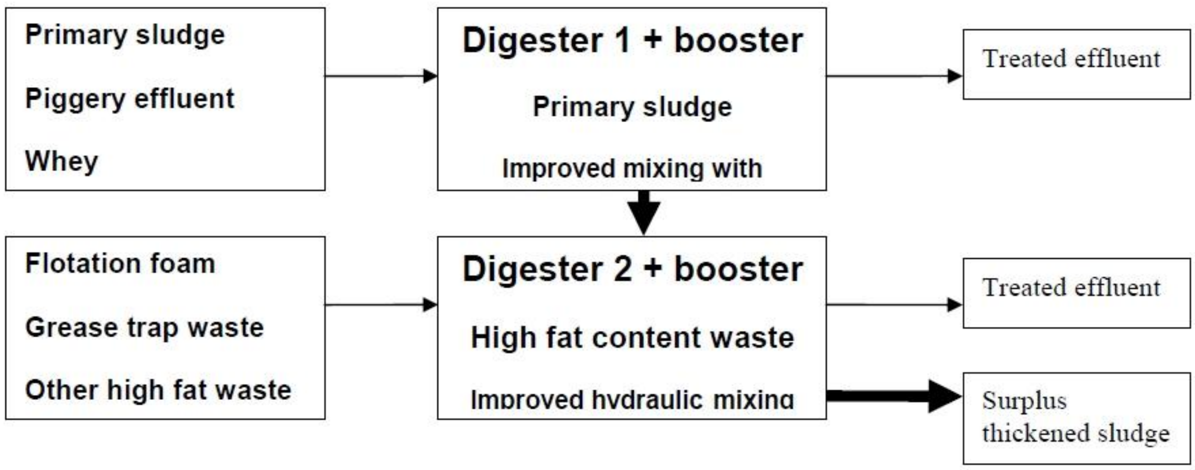

Figure 2 Conceptual Design of Liquid Waste Deliveries

Photograph 3 Liquid Waste Reception Facilities

2.2.2 INSTALLATION OF SLUDGE BOOSTER

Due to insufficient budget unfortunately the sludge booster although purchased in 2010 was not installed until 2012. The sludge booster consists of an Andritz PDL900 drum thickener (photograph 4 below) installed in a refurbished shipping container next to the digesters. The sludge is drawn off the digesters and is thickened to 8% with the addition of 4-6kg/ds of poly electrolyte and then returned to the digesters. The poly electrolyte addition is achieved through the use of a TOMAL automated batch plant which requires minimal staff input.

The sludge booster is designed to triple the retention time of the solids within the digester allowing for a shortened hydraulic retention time in the digester and thereby increase biogas production. Sludge washout is counteracted by the booster effect enabling the retention of the solids within the digesters, in addition the digesters discharge a higher quality filtered effluent with a lower solids content.

Booster technology gives an additional process robustness to the digesters and has uncoupled the solids residence time and hydraulic residence time. The thickener capacity in the containerized facility is fully automated with polymer dosing and for a mixed liquor throughput capacity of 600 m3/day of digester contents.

Currently the sludge booster is connected to Digester 2 only; this has been designated as the industrial digester and receives both primary sludge and additional high strength waste. This has been done to ensure that in the event of digester problems with digester No. 2 PNCC will still have an available digester to treat the daily primary sludge production from the WWTP.

The total upgrade costs for the installation of the hydraulic mixing system, liquid waste reception facilities and booster construction was $1.4millon.

Photograph 4 Photo of Andritz Sludge Booster

2.2.3 SOURCING HIGH STRENGTH WASTES

The table below highlights the mix of potential wastes that were investigated at the time the project was being initiated as being suitable for introduction into the digesters. Potential supplies were identified within a range of distances from the WWTP we were looking initially for organic material in a 10km, 20km, 30km and 50km radius Costs are driven by distance, volume, consistency, strength, potential for contamination, other alternatives and sunk capital investment.

List of used waste materials:

Supplier	Flowrate (wet wt)				TS %	VS (% of TS)	VS (t/day)
Venison Packers (paunch only - not usable)							
Land Meat NZ (paunch only - not usable)							
CMP (too small daily volume to be significant)							
PN TTS Grease trap waste (Paul Ward) sample analysed by WS	50	m3/wk	7.14	t/d	7	80	0.40
Additional Grease trap waste (Wellington Paul Ward) will be thickened	350	3/month	11.48	t/d	7	80	0.64
PNCC primary sludge (digester #1)	770	m3/wk	110.00	t/d	4	80	3.52
Speirs Food (cabbage, lettuce offcuts etc.)	950	t/yr	2.60	t/d	14.6	92	0.35
Fonterra DAF waste (70 % FOG in VS as specified by PNCC)	105	t/wk	15.00	t/d	15.0	92	2.07
piggeries (happy hog fresh manure)	100	m^3/wk	14.3	t/d	5.0	85.4	0.61
other hypothetical piggeries	100	m^3/wk	14.3	t/d	5.0	85.4	0.61
Fonterra whey (digester #1)	150	m^3/wk	21.4	t/d	6.4	90	1.23
Fonterra whey (digester #2)	70	m^3/wk	10.0	t/d	6.4	90	0.58
Total			**206**	t/d			**10.0**

Table 1 Potential Organic Wastes For The Digester

Piggery waste was initially seen as a high value waste product for introduction into the digesters as it is similar to human waste, readily available and relatively easily transported. Unfortunately in practice it has proved virtually impossible to source any piggery waste. Pig farmers either already have a low cost method of disposal or existing buyers for their waste products. When PNCC approached local piggery farms there was virtually no interest in paying PNCC for the privilege of taking their waste in fact they have all stated that PNCC should be paying them. Efforts have continued sporadically over the past few years to identify sources of piggery waste, but overcoming the barrier of existing low cost disposal plus transport has proved insurmountable to date.

Currently PNCC receives waste from the Longburn Fonterra Dairy Factory (up to 15m³/day), Fonterra Ice Cream Plant (8m³/day) and Grease Trap Waste. The new waste is charged on a cubic meter basis as measured at the liquid waste facility with the current charge set at $30/m³.

2.2.4 UPGRADED DIGESTER GAS PRODUCTION

The upgrade works have been completed with the exception of the connection to digester No.1 which is scheduled to be completed in 2017/18. The upgraded digesters have demonstrated stable operation under the increased loadings and increased biogas production as can be seen in figures 3 and 4 below. PNCC has not experienced any issues with foaming or fat layers in the upgraded digesters at loading rates of up to 15m³/day of dairy factory DAF which occurs during the peak dairy season.

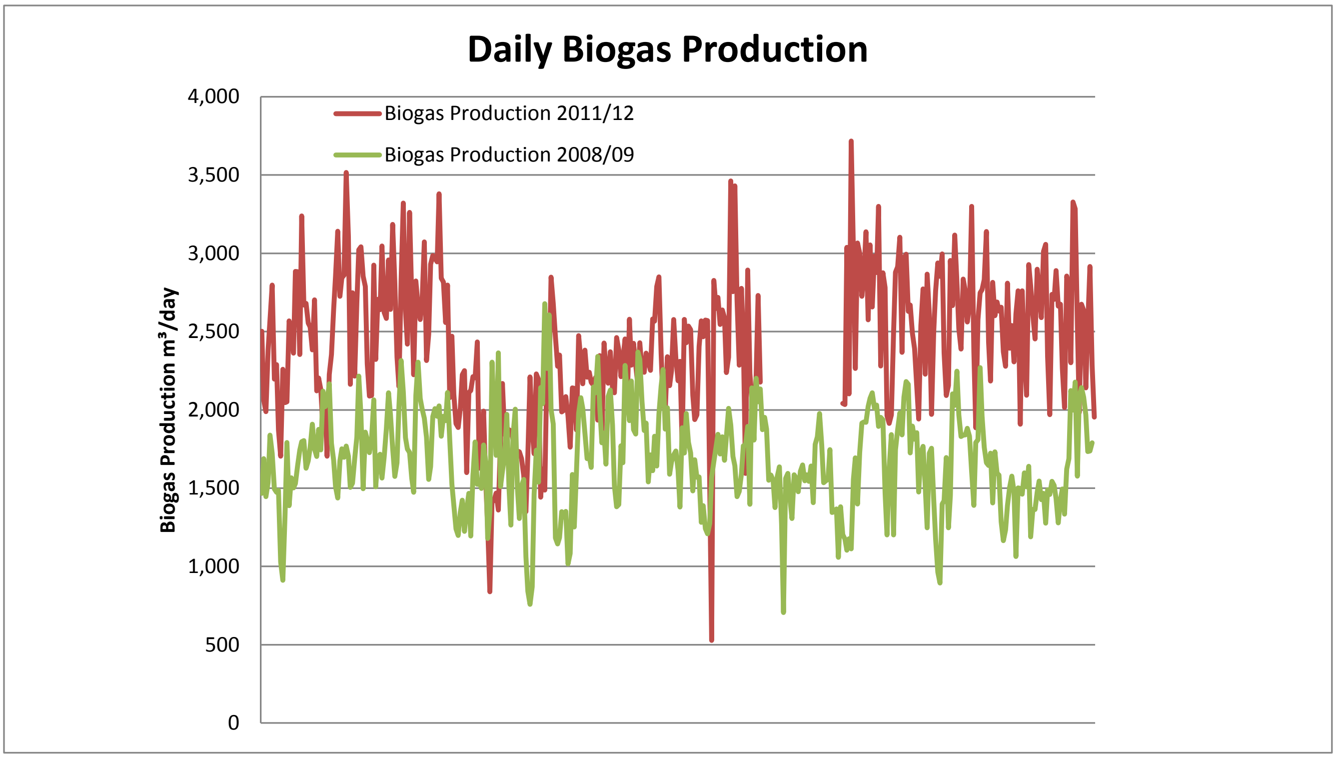

Figure 3 Daily Biogas Generation Comparison 08/09 v 11/12

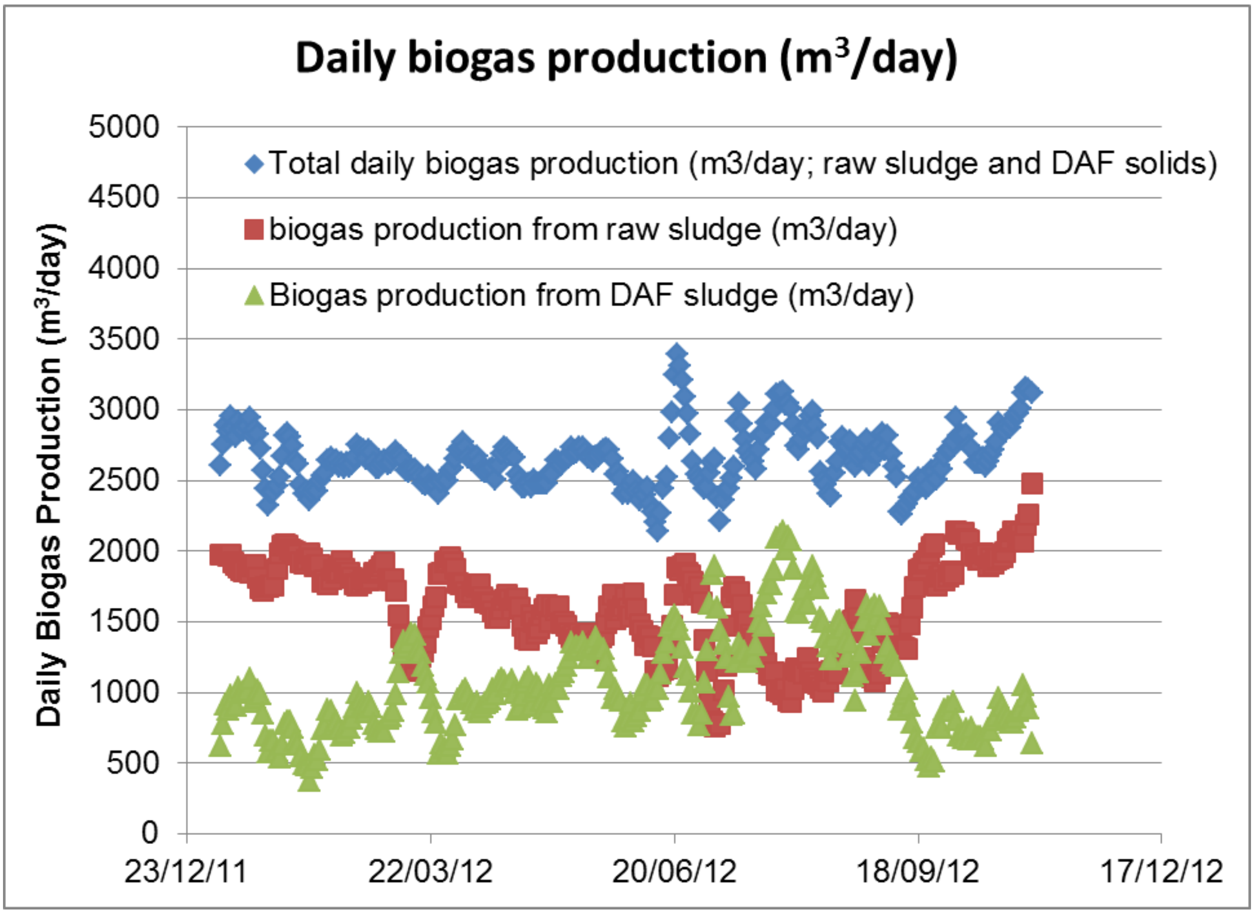

Figure 4 Daily Biogas Production v DAF Deliveries

2.2.5 PITFALLS AND UN ANTICIPATED CONSEQUENCES

There have been considerable delays in completing this project which have meant that Council has not yet achieved the desired results in terms of a financial return. In addition the complexities of retrofitting and constructing upgrades to two 45 year old digesters has thrown up a number of un anticipated issues that have delayed realising the full potential of the project.

The delay in the installation of the sludge booster into the digesters restricted the total volume of additional solids we could feed into the digester. On the first attempt to feed the new DAF waste into digester No.2 was too ambitious and introduced too much without giving the digester bacteria time to properly adjust, this resulted in an adverse reaction in the digester and the supply of DAF waste had to be had to be stopped while the digester recovered.

This revealed another issue that had not be appreciated at the time, in that Council had a contract with Transpacific Technical Services to receive and treat the DAF in the digesters but with no alternative disposal route identified during those times PNCC were unable to take it. Fortunately Council has a composting operation underway on the neighbouring closed Awapuni Landfill to which the DAF was able to divert to for the duration of the recovery process.

This highlighted for PNCC the need to properly plan out new waste sources, and has made Council much more cautious in accepting new wastes on a permanent basis. Either the supplier of the waste material will need an alternative disposal route for their waste in the event that Council cannot take it or PNCC will have to determine an alternative disposal site. Not all wastes are suitable for composting and there may be considerable costs involved in transporting contracted wastes to another site for treatment.

The delay in constructing the sludge booster resulted in reduced volumes of biogas generation throughout 2010 and 2011 with a corresponding reduction in generation potential.

This project has highlighted the many unknowns encountered when retrofitting and upgrading existing infrastructure that is in many cases up to 50 years old. By changing the nature of the operation of existing facilities it has been found that the existing infrastructure can become stressed beyond its normal state and subsequently fails. One such item was the waste gas flare that is attached to the digesters; this had been used to burning the low volumes of gas previously produced. Once the upgraded digesters started producing increased volumes the old flare struggled to keep up and at times the volume of gas being passed through the flare actually blew the flame out.

This has necessitated the replacement of the flare with a larger unit capable of handling the increased flows with the associated additional costs. In addition it was found that portions of the existing biogas pipework were undersized and required up sizing. Due to the uneven gas production between the two digesters it has necessitated further automation of the valves of the primary sludge digester in order to balance the flows and prevent excessive draw down of the floating lid due to the lower pressures resulting from its lower gas production.

The increase in gas production also highlighted problems with the floating lids on both digesters; shortly after the new biogas systems were commissioned a gas leak was detected in the attic space of one of the lids. It is surmised that increased gas production in turn increased pressures under the lid of digester 2 and caused an already weak section on one of the old pearth lances to fail and leak gas into the attic space. This necessitated an inspection of the interior of the lid which in turn meant that the digester had to be cooled down and emptied before any intensive inspections could be carried out.

The subsequent inspection then revealed extensive corrosion of the lid especially along the outer edge of the base and rafters, it was decided to re commission the digester and schedule a full refurbishment rather than replacement in 3 years time. Again this incident further set back gas production/energy generation for six months while the problem was resolved as the remaining digester had to treat the full daily primary sludge volumes which meant no additional wastes could be accepted for that period.

A further incident delayed the return to full production. Shortly after re commissioning of digester No.1 began an unknown material entered the plant and was subsequently fed into digester No.2 and caused an adverse reaction which caused it to get out of balance with increasing acid production and suppressed methagenic activity. This was picked up by the plant operators weekly testing showing increasing VFA's and decreasing pH. After several days a decision was made to stop feeding the digester and let it rest in the hope that it could recover. Lime was also dosed daily at 500kg/day to counter react the pH in-balance and raise alkalinity. During that period the daily sludge production had to be diverted to the existing sludge lagoons for approximately 14 days before gradually feeding into the digester again. This process took several weeks to avoid overloading the recovering bacteria and tipping it over again.

Re-starting of digester No.1 was further delayed due to the time required for digester N.2 to recover as it was critical that the empty digester not be re-seeded using "bad" bacteria.

This incident has re enforced the need for a robust Trade Waste monitoring program. Whilst there is no known noxious or toxic type of industries located within Palmerston North it is obvious that this does not prevent undesirable or toxic material from entering the waste stream and subsequently impacting the performance of the digesters. The risk from illegal operations such as meth labs is unknown at this point but the recent incident could have originated from illegal substances being tipped down the drains. PNCC samples all tankered industrial wastes that are fed into the digesters and these samples are stored for up to one month in case of a digester problem, these samples can then be tested later to try and identify the contaminant. The new co substrates must be free of substances that can inhibit anaerobic digestion such as chemical contaminants, plastics, paper, stones or bones.

In addition PNCC has installed a S::CAN device supplied by DCM Process Control on the influent to the plant and have commenced finger printing the discharge from all our major Trade Waste Customers (20 in total) This will enable identification of trade wastes as they enter the plant which in turn should help with identifying the offending party in the event of a digester problem.

3 CONCLUSIONS

These projects are examples of successful implantation of PNCC's Sustainable City Strategy and the Going Greener brand. The program of digester improvements and construction of a new biogas generation facility has been successfully implemented and PNCC has successfully changed from operating two under performing low rate municipal sludge digesters to high rate industrial sludge digestion utilizing high strength fatty wastes. The digester upgrade has proven to be robust and the digesters shown resilience in accepting new co-substrates with very little difficulty.

The process of sourcing and introducing new wastes into the digesters has taken longer than desired and proven to be challenging in overcoming the price barrier and existing disposal routes of potential suppliers. The requirement for a robust Trade Waste management system is now appreciated and has reinforced the need to thoroughly investigate new co substrate sources before these are introduced into the digesters to ensure that there are not any adverse reactions

One of the greatest benefits of the improved PNCC Totara Road digester facility is that it can digest a wider range of additional industrial waste including piggery manure, whey waste, grease trap waste, and selected food industry flotation foams. Digesting this waste produces an increase in biogas - which means PNCC ultimately avoids natural gas purchase costs and generates new revenue from the acceptance of new waste streams.

By viewing organic waste as a resource, PNCC is not only helping to divert organic material from water and landfill disposal it is finding a way to generate 'greener' revenue streams well into the future.

ACKNOWLEDGEMENTS

PNCC is grateful to spiire Consultants and in particular Jürgen Thiele for his work in improving the performance of the digesters and for the advice and assistance offered during the upgrade and to Rob Green Water and Waste Manager PNCC.

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