RENEWABLE ENERGY GENERATION THROUGH CO-DIGESTION WITH NON-SEWAGE WASTES

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ABSTRACT

Conventionally biogas production and renewable energy generation utilising digestion at wastewater treatment plants (WWTPs) has only been considered cost effective at a large scale, unless the facilities have pre-existing digesters and primary sedimentation tanks. The perception is that small WWTPs (less than 20 MLD) - are limited in opportunities for beneficial biogas and renewable energy generation. This view has arisen from two key factors: Small facilities have limited sludge volume which typically means low gas production, and; the capital cost associated with installation of new infrastructure is proportionally high, meaning these facilities are not cost-effective at a small scale.

Recent global experience has shown that smaller WWTPs can produce biogas cost-effectively. The key to success is the introduction of non-sewage high-strength waste streams (HSWs). These HSWs can be co-digested with sewage sludge to boost biogas production and generate electricity to offset consumption, and in some cases, export power to the grid. The increased biogas yield, coupled with the income generation obtained through "tipping fees" for accepting the HSWs, improves the business case for these facilities. Other advantages include a significant reduction in landfill waste and reduced greenhouse gas (GHG) emissions.

KEYWORDS

Renewables, biogas, co-generation, digestion, efficiency, high strength waste

1 INTRODUCTION

Drivers such as a reduction in operating costs and the movement towards renewable energy generation has seen increasing interest in, and installation of, co-digestion facilities in recent years – bringing the waste and water sector together in many instances. Internationally the waste sector is recognising the resource potential of utilising waste organic matter for resource recovery in varying forms, from nutrient extraction to energy production, to help offset some of these challenges. Co-digestion facilities are typically wastewater treatment plants with existing Anaerobic Digestion (AD) where the digesters have spare capacity to accept additional waste. The facilities produce biogas which can be used onsite and/or converted to electricity to offset existing power requirements or export power to the grid.

Several successful co-digestion facilities have been implemented in North America involving small and large scale facilities with existing anaerobic digesters (Chung et al., 2010; Kabouris et al., 2012). These projects were located at facilities which had pre-existing digesters with sufficient capacity for accepting and co-digesting the high strength wastes to benefit from increased biogas production, meaning the capital expenditure could be minimised due to utilisation of existing infrastructure.

Generally, it is thought that smaller wastewater treatment plants (WWTPs) - typically less than 20 MLD in size - are limited in opportunities for beneficial biogas generation due to two key factors (Gebrezgabher et al 2010):

1. Limited sludge volume (due to size) and consequential lower biogas production

2. Proportionally high capital costs associated with installation of the new infrastructure required to generate biogas and produce power and heat for use as a renewable energy source.

However, recent experience gained through two conceptual level projects in Victoria, Australia (2012), has shown that small-scale wastewater treatment facilities, without pre-existing primary clarifiers and anaerobic digesters, can also yield a positive business case for a co-digestion facility. The key success criteria for these projects was the introduction of HSWs for co-digestion with sewage sludge to boost the biogas production. The significant increase in biogas yield arising from the addition of these HSWs resulted in all options investigated realising the potential to produce power for onsite consumption, and in many cases producing surplus electricity for export to the power grid and the generation of additional revenue. Further, through sensitivity analysis, it was found that the key success factor was the cost charged to the HSW providers, in lieu of their current tipping fee, becoming revenue for the owner-operator. The revenue from the HSWs significantly offset the projects capital and operating costs, and resulted in projected paybacks less than 5 years in some instances.

The other advantages of these facilities are the beneficial utilisation of the high-strength wastes in producing renewable energy, a reduction in waste to landfill, and a decrease in GHG emissions (Jonassen Industrial Projects, Banks et al 2011).

2 COMMON BARRIERS TO CO-DIGESTION FACILITIES

The drivers outlined above, coupled with the success of projects overseas, begs the question - why aren't these facilities increasingly being installed throughout the world, and, more locally, in New Zealand?

Regional AD facilities catering for a waste providers are quite common in the USA, UK and Australia. Co-digestion facilities are also operating successfully in the UK and USA, and these facilities are gaining traction in Australia also, however these facilities have not yet made significant inroads into New Zealand. While these facilities are successful and economically viable overseas, it is not simply a matter of transposing costs and viability from overseas experience into New Zealand. Different economic considerations (power costs, fuel costs, transport distances, waste disposal costs) and New Zealand specific technical constraints (nature of industrial waste, farming practices, and environmental regulations) suggest that it would be prudent to use an optimised New Zealand specific approach adapted to the local conditions (J Knight 2006).

Typical barriers to these projects emulate those experienced overseas and common to many innovative projects; footprint and land/infrastructure availability, regulatory issues, funding, and a lack of experience – both from a technical design, and construction/operation perspective. Other barriers faced include the NIMBY Syndrome (J. Mata-Alvarez, et al) and securing constant and consistent feedstocks.

2.1 REGULATORY ISSUES

The majority of existing AD capacity is operated by water and sewerage companies. A number of these companies are now investigating the potential to utilise their spare digester capacity by co-digesting sewage sludge with other biodegradable wastes, however, there are a number of regulatory barriers, such as under what regulations are biogas and digestate controlled, that prevent this potential from being realised (http://www.ciwem.org/knowledge-networks/panels/waste-management/co-digestion-of-sewage-sludge-and-waste.aspx).

Environmental regulatory constraints such as increased carbon footprint from transportation of feedstock and digestate to the WWTP is also important to consider. Who will own the emissions associated with that transport – the WWTP owner-operator, or the waste provider who would have to transport and dispose of that waste via another route if not to the co-digestion facility? Other environmental issues include incomplete combustion in combined heat and power plants as well as storage of waste and digestate.

Additional regulatory and environmental considerations include planning and zoning considerations (for greenfield sites), site development due diligence, environmental management, buffer distandces, stakeholder approvals, the types of waste being input to the co-digestion facility, community considerations, end uses, and engagement and communication.

2.2 FINANCIAL ISSUES

To enable water companies to develop co-digestion facilities a number of commercial, financial and contractual factors need to be considered, particularly to warrant a sound business case. Some of the key financial considerations will include the overall cost of the project and the availability of debt and equity as well as the attractiveness of project related cash flows to the private sector – i.e. there is not competing capital demand.

Quality assurance, contractual obligations, and public liability issues associated with outputs/products being fit-for-purpose and consistent in quality is also a key risk to the water company vesting in a new venture. Stranded Asset Risk is also key to business case development for a co-digestion facility, which would be created by the dependence on customers for inputs and purchase of outputs.

The ability of water companies to receive solid waste from producers who fall outside their regulated and traditional customer base is a key barrier to overcome. Particularly given the biogas generated will be utilised on site to offset costs, and funded through existing consumer water bills. The non-regulated revenue implications arising from the additional revenue streams generated by the facility may require buy-in and input from the Essential Services Commission, or similar entity.

Price determination for end products is also a key financial issue – i.e. there is a competitive, established market for the product which follows pricing increase trajectories and market driven/competitive pricing decreases. There is a risk that the owner-operator could not justify following such fluctuations in market pricing if the cost to produce biogas through the facility has not increased, however to stay competitive the owner-operator would need to follow market pricing decreases, even though the cost to produce biogas has not decreased.

Competitive Neutrality (http://www.pc.gov.au/agcnco/competitive-neutrality) is another key consideration and seeks to ensure that government businesses do not enjoy competitive advantages over private sector competitors simply by virtue of their public sector ownership. Waste service providers will request a level playing field so that they do not experience any competitive disadvantage to water companies, who may be in an autocratic position and able to offer significant discounts (http://www.ciwem.org/knowledge-networks/panels/waste-management/co-digestion-of-sewage-sludge-and-waste.aspx). Therefore economic constraints such as how additional investment would be paid for and how revenue generated would be shared between the water and waste management sector is a key consideration when investigating the feasibility of an AD facility.

2.3 TECHNICAL ISSUES

Technical issues with these facilities centre on the operation of an AD facility. Due to the increased variation in feedstock's which will arise from the number of different incoming waste streams, there is an increased risk of foaming. Digesters prefer consistent incoming waste streams, both in terms of quantity and quality, and an increase in waste sources corresponds to an increase in the AD performance risk.

Other technical risks to consider include those assosciated with handling and treatment of the incoming waste streams. The waste transport and delivery to site is also a key risk – how is the waste offloaded? Is the facility set up to monitor the incoming waste for quality and quantity delivered? Once on site, there is the risk of pipes blocking due to solidified fats, which will require heating and constant mixing. Many of the incoming wastes will require pre-treatment comprising sorting, mulching, separating, mixing, heating and storage.

2.4 DEMOGRAPHIC ISSUES

Co-digestion of HSWs with sewage sludge at existing wastewater treatment plants offers an opportunity to achieve financial viability for AD whilst reducing waste transportation requirements (lowering the carbon intensity of the collection/transportation process). For example, for sewage sludge AD to be financially viable requires about 100,000 population, as does food waste AD. Co-digestion would be viable for a town of 50,000 people but mono-digestion would not and wastes would have to travel to a centralised site with the associated transport carbon emissions. The water industry has a significant experience base on AD, and to a lesser extent in relation to co-digestion. (http://www.ciwem.org/knowledge-networks/panels/waste-management/co-digestion-of-sewage-sludge-and-waste.aspx)

However locating these facilities in urban centres poses additional problems – particularly when facing the NIMBY syndrome. These barriers can be overcome through education and consultation early in the piece, but warrant significant efforts from the owner-operators if the project is to be successful.

2.5 FEEDSTOCK ISSUES

There are a number of HSWs which can be anaerobically digested, particularly when combined with domestic sewage sludge. As discussed above, the main issues concern the quality of the feedstock and the ability to ensure a consistent feed into the AD facility. Additional to this the ability to remove contaminants, which can negatively affect digester performance, is critical.

3 CO-DIGESTION

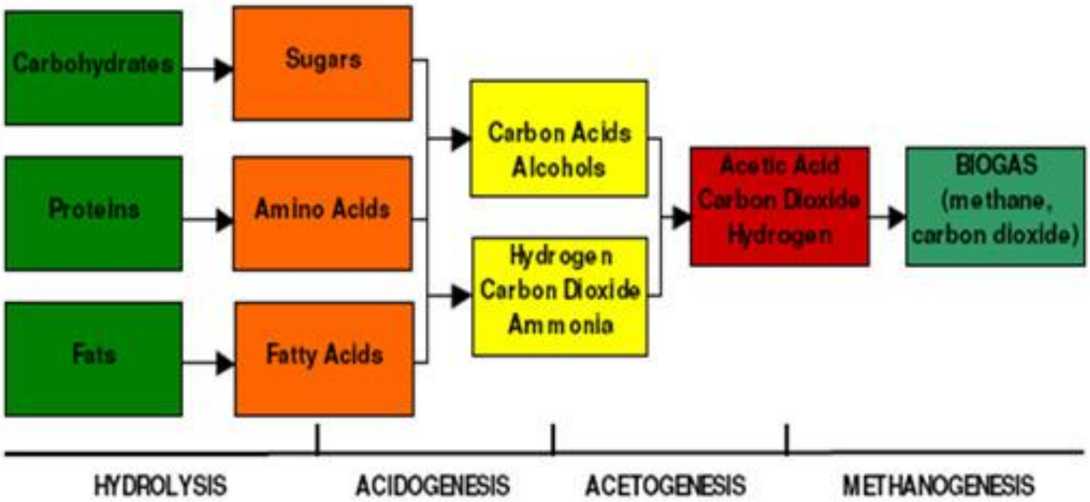
Anaerobic ("without oxygen") digestion is a biological process employed for sludge degradation and stabilisation. The process uses microorganisms to break down biodegradable material in the absence of oxygen to convert solids into a humus-like material and to recover resources such as biogas, which can be used for its energy potential. Other benefits include a reduction in the volume of waste going to landfill, and decreasing environmental footprints of the waste generator's operations.

The co-digestion of various wastes can provide additional positive impacts, including optimising the biogas generation process, as well as creating a far reaching resource recovery project where various industrial wastes can be managed in a more sustainable way.

3.1 PROCESS OVERVIEW

The digestion process begins with bacterial hydrolysis which breaks down organic polymers such as carbohydrates, fats, proteins, amino acids, fatty acids and sugars to make them available for other bacteria. The sugars, fatty acids, and amino acids are eventually converted into methane and carbon dioxide following acidogenesis, acetogenesis and methanogenesis. This process is illustrated in Figure 1 below.

Figure 1: Biogas Production Process using Anaerobic Digestion



http://www.ccibioenergy.com/bioenergy-platform/what-is-ad

The key thing to note from this diagram, and the anaerobic digestion process, is that it is the carbohydrates, fats, proteins, sugars, fatty acids and amino acid content which is the critical "food source" for methane (and biogas) production. Therefore waste streams which contain these compounds in higher concentrations, will result in higher biogas production.

The biogas produced through this process typically has a high methane and energy content (60-70% of the energy content of natural gas), with energy content typically in the range of 22,000 - 24,000 kJ/m3.

Anaerobic digestion has additional benefits including reduction in the volume and mass of the solids residuals (biosolids) produced, stabilisation and pathogen reduction for the biosolids which can allow for their beneficial reuse, and decreasing the environmental footprint of the WWTP.

3.2 ANAEROBIC DIGESTION TECHNOLOGIES

There are a number of technologies which can be considered for energy production through the generation of biogas in sewage treatment plants. The processes available include various types of anaerobic digestion either in large tanks (digesters), or via a lower-energy passive covered-lagoon system with anaerobic lagoons generating biogas. The key strengths and weaknesses of the available anaerobic digestion technologies are summarised in Table 1 below:

Table 1: Available Anaerobic Digestion Technologies

Anaerobic Digestion Type	**Process Summary**	**Strengths**	**Weaknesses**
Mesophilic Anaerobic Digestion (MAD)	Occurs optimally around 35-38 °C	Easy to operate More tolerant to changes in operating conditions compared to thermophilic digestion Medium gas production and volatile solids destruction	Larger reactor volume and higher capital cost Potential for high strength waste to “breakthrough” due to incomplete digestion
Thermophilic Anaerobic Digestion (TAD)	Occurs optimally around 50-57 °C	Higher biological activity due to increased temperatures results in smaller reactor volumes and lower capital costs Higher temperatures can facilitate increased pathogen destruction	Medium-low process stability - requires increased operational attention Higher energy consumption for process heating Typically not used in small facilities
Lagoon Digestion	First stage is anaerobic digestion. However, some plants are known to have aerated lagoons upfront Membrane lagoon covers capture biogas	Reduced sludge production Lagoons have a 30 year life No mechanical equipment required for gas production Simple to operate	Low rate of stabilisation Large footprint Require covers over the lagoons – difficult to properly cover and seal over a large area No process control – therefore difficult to control/maintain Contents of lagoons are susceptible to temperature fluctuation – e.g. temperature drop could adversely impact lagoon health
Temperature Phased Anaerobic Digestion (TPAD)	TPAD is TAD for 5 to 10 days followed by MAD for 10 to 15 days	Increased pathogens destruction Able to deal with co-digestion of grease and comingled food waste Medium-high process stability Mesophilic digestion following thermophilic digestion helps prevent breakthrough odours	Increased process complexity Typically not used in small facilities Some wastes are more challenging for stable operation as TPAD has lower stability than Two Phase Acid-Gas Digestion
Two Phase (Acid-Gas) Anaerobic Digestion	Two Phase Acid-Gas Digestion is similar to TPAD in that solids are digested in two-phases First (acid) phase has a hydraulic retention time (HRT) of 1 to 3 days Second (gas - methane) phase typically has a 10 to 14 day HRT	Reduced foaming and improved gas yield Suitable for small facilities Very high process stability Reduced digestion volume by 30 – 50% results in low capital cost	More process complexity Requires consistently high organic loading of the acid reactor

3.3 PREFERRED WASTE SOURCES

Most wastes currently being sent to landfill can be considered for co-digestion. However, some wastes are preferred over others for biogas production, typically dependent on their energy content and physical characteristics. Wastes which are typically available and have been considered for these types of facilities include:

- Brewery Processing Waste – approximately 24 m3 energy output per tonne
- Cheese Whey Processing Waste – approximately 15 m3 energy output per tonne
- Paper/Pulp Waste
- Greasy waste / Fats Oils and Greases (FOG) (i.e. grease trap pump-outs) approximately 88 m3 energy output per tonne
- Residential Food and Green Waste (via trucked collection)
- Residential / Commercial Food waste (organics rubbish bins)
- Food Waste (from manufacturers, markets or supermarket chains) approximately 41 m^3 energy output per tonne

Greasy wastes, food waste and FOG are preferred over wastes such as lawn clippings or grape skins from winery waste as the components of these (skin/stalks) can be difficult to digest. However it should be noted that solid food waste can have considerably higher pre-treatment requirements when compared to other waste types and this should be considered when evaluating the cost effectiveness of its use in co-digestion.

Many non-sewage wastes are seasonal in production (i.e. dairy processing and meat production such as lamb processing) and there are a number of drawbacks in using seasonal waste sources. One of the key concerns is the over-sizing of facilities which may create additional and unnecessary capital expenditure. Anaerobic digestion requires continuous feed (quality and flow), therefore the required storage would need to be sufficiently large to store seasonal waste when it is generated, and then slowly feed the waste continuously into the digestion process over the low season. This increases the potential of the digestion process becoming less stable and the likelihood of foaming occurring as the loading rates are changed. The additional capital investment required for the larger storage and processing facilities is also significantly higher than any benefit realised from the addition of a seasonal waste stream.

The preferred waste material for co-digestion will also depend on the availability of the waste at an economic haul distance and expediency (i.e. can it be held at the source until needed or must it be accepted at the whim of the generator) as well as the biogas yield potential of that waste stream.

4 CASE STUDY

A case study from Victoria, Australia for co-digestion of high-strength wastes (HSWs) and municipal wastewater treatment sludges was a recent conceptual level project for Yarra Valley Water. This project comprised feasibility analysis and conceptual design of co-digestion and co-generation facilities related to three small wastewater treatment facilities, each less than 20 MLD, without pre-existing primary clarifiers and anaerobic digesters.

4.1 BACKGROUND

Yarra Valley Water (YVW) engaged CH2M HILL to investigate the feasibility of renewable energy generation through anaerobic digestion and co-digestion of waste at up to four separate sites. The main objective of this project was to identify a preferred site for the facility and provide YVW with documentation to support the development of a robust business case for a new co-digestion facility. The project included the following components:

- Assessment of the available biogas generation technologies and waste sources available
- Recommendations on the preferred technology and waste sources

- Conceptual level assessment of likely biogas generation and development of costs
- Assessment of the likely revenue generation and payback period through export of power to the grid, funding and other government incentives
- Assessment of the likely risks, opportunities and overall feasibility of a biogas generation plant at one of the four identified sites.

4.2 PROJECT OVERVIEW

This project included the assessment of four YVW owned sites, two of which were existing wastewater treatment plants (WWTP), one a proposed WWTP, and the fourth site was an unidentified "independent site" which did not include wastewater treatment. The fourth site was used as a "control" site, and did not include the addition of wastewater to the digestion process.

For the purposes of this project the infrastructure required to enable biogas generation and utilisation was identified as an anaerobic digestion facility, power and heat cogeneration facility, biogas handling and storage, and various waste receival, handling and storage facilities.

Additional infrastructure included primary sedimentation, sludge thickening and handling, and electrical infrastructure upgrades or the installation of new electrical infrastructure (power transformers).

The options for each of the four sites were established with a view to providing an array of different systems that can be compared from a cost and biogas generation performance perspective. For example, by considering primary treatment at one site and comparing this to a similarly sized WWTP that does not have primary treatment; the impacts of these differences can be identified and compared. The options assessed were:

- Site 1 (Brushy Creek 10 MLD) – primary sedimentation is not provided at Site 1
- Site 2 (Aurora WWTP 10.2 MLD) – primary sedimentation has been included to allow identification of the cost effectiveness of including (or excluding) primary sedimentation at Sites 1 and 2 given their similar available wastewater flows
- Site 3 (Kalkallo WWTP 40 MLD) – primary sedimentation is included at varying scales, from no primary sedimentation through to primary treatment of the full 40 MLD of available flow. Varying inputs were considered (differing ratios of HSW streams) to determine the effect of increasing or decreasing certain HSW volumes
- Site 4 (Independent Site) – did not include primary sedimentation, because this site has no incoming wastewater. Two anaerobic digestion alternatives were considered to confirm the preferred anaerobic digestion alternative.

4.3 PROCESS AND TECHNICAL OUTCOMES

After an assessment of the advantages, disadvantages and high level costs for various digestion available technologies, it became evident that the preferred anaerobic digestion technology which should be adopted at the sites is two-phase acid-methane digestion mainly due to its high stability, low footprint, and low capital and lifecyle cost.

To aid biogas generation at the four sites identified, the addition of HSW streams was assessed to identify the preferred wastes to include in the assessment including:

- Trucked Process Waste (dairy, brewery or winery)
- Fats Oils and Grease – FOG (grease trap pump-outs)
- Residential Food and Green Waste (via trucked collection)
- Residential / Commercial Food waste (organic wastes bins)
- Food Waste (markets or supermarket chains)
- Paper/Pulp Waste.

The most suitable HSW streams for biogas production were found to be the fats, oil and grease (FOG) and food wastes. Cheese whey and brewery waste were considered strong candidates which can result in high biogas yield. The assessment included estimation of the likely biogas yield per ton of waste type to rank the HSW streams and for the preferred technologies the following yields were estimated. Other wastes such as dairy processing and winery waste were not considered attractive for the purpose of this evaluation due to factors such as their lower potential biogas yield and seasonal availability. Green waste was also not considered an attractive candidate due to its lower biogas yield. As a result of this assessment, the recommended waste streams which were assessed in this project were FOG, food waste, brewery waste and cheese whey process waste. All streams were co-digested with wastewater sludge at all sites except Site 4.

4.4 RESULTS

It was found that the addition of primary sedimentation to the biogas production process significantly increases the biogas yield and reduces the overall energy footprint of the site. When comparing the Brushy Creek and Aurora sites, all four options at the Aurora site (which included primary sedimentation) were found to provide surplus electricity which could be exported to the grid as additional revenue. Only one of the Brushy Creek site options was found to generate surplus electricity. However, it is noted that the cost of the primary sedimentation and additional sludge thickening facilities associated with this process were found to offset the benefit of this additional biogas yield.

Both options for the independent site yielded significant biogas quantity, sufficient to provide heat for the digestion facilities and to produce surplus power for export to the grid. However, it is noted that this site is associated with increased risk due the potential for increased process instability and/or nutrients deficiency associated with the lack of the municipal wastewater sludge feedstock.

For the sites and scenarios which did supply surplus energy, both Brushy Creek and Aurora are located within close proximity of supply lines and high voltage connections and transformers, meaning that the infrastructure upgrade requirements for export of electricity to the grid at these sites is not likely to yield significant additional costs.

Incoming waste stream processing will be required at each of the sites to enable the addition of HSW streams to the biogas generation process. The need for a secure system and robust procedures for receiving HSWs at the proposed sites is significant as there is a risk of receiving “unspecified” or “untested” waste if this process is not controlled.

4.5 FEEDSTOCK TREATMENT

In the case of codigestion of the HSW streams with municipal sludge, screened food waste slurry and liquid FOG, cheese whey and brewery waste streams would be combined with municipal sludge and the acid-gas reactor’s heat exchanger recirculation line, before being introduced to the first phase of the anaerobic digestion process – the acid reactor. Following stabilization of the solids stream in the anaerobic digestion system, the solids are withdrawn and transported for further treatment, disposal or beneficial reuse. The most cost effective and simple biosolids disposal option is likely to continue to be discharge to the sewer (as is currently performed at Brushy Creek and Aurora). Recommendations for alternative biosolids management at each of the sites were also made based on the risks and advantages of each technology, land availability, cost, biosolids handling issues and the potential market for the final product. The recommendations suggest that thermal drying would be the recommended technology, based on the assumption that discharge to the sewer would no longer be a viable option. This recommendation was based on economic criteria and consideration of social and environmental criteria needs to be included prior to confirming the biosolids treatment technology.

4.6 REVENUE STREAMS

The power cost was $0.12/kWh. An important incentive for generating renewable energy is the premium provided through electricity fed back into the grid should surplus be produced. YVW is likely to be able to sell power back into the grid for approximately $0.05 per kWh. One other potential revenue stream which has been included in this assessment is that of tipping fees for the disposal of HSW streams to YVW owned sites. A local firm has completed a study in parallel to this work which investigated the available waste sources, volumes and other details related to cost, such as existing tipping fees which will determine the likely fee that YVW can expect to recoup through collection of the additional waste streams. The likely tipping fee has been advised as $129/tonne ($117/ton) of waste.

4.7 FINANCIAL COMPARISON

Conceptual level capital cost estimates were generated for the preferred option at each site. The Brushy Creek and Kalkallo sites were found to have the shorter payback periods at 3.6 and 3.2 years respectively. There is significant sensitivity in the adjustment of the tipping fee when calculating the overall payback. Several options were re-evaluated with a lower tipping fee of $25/tonne (original estimate was $125/tonne) of waste and it was found that the payback periods increased significantly at the two preferred sites (Brushy Creek and Kalkallo) to 8.2 years and 14.1 years respectively (increasing the payback period by 3–4 times). This is a significant increase and therefore determination of the likely tipping fee is critical to the business case for this project. However, even at the higher tipping fees, a positive business case may be made despite the small size of the existing facilities and lack of existing primary clarifiers and digesters. A conceptual layout of the codigestion facilities is presented in Figure 1. It can be observed the facilities require a small footprint compared to the existing WWTP facilities.

5 IMPLEMENTATION OF A BIOGAS PRODUCTION FACILITY

There are a number of considerations when investigating the feasibility of implementing a biogas production facility. Some of these include planning and regulatory approvals, legislation, disposal of the by-products (digestate and biosolids), odour control, and of course, the expected lifecycle benefits and payback period.

Some of the key environmental approval and planning considerations to consider for a co-digestion facility at an existing WWTP include:

- Existing Environmental Approvals:
    - Will the buffer distances meet the Environmental Protection Authority (EPA) guidance for current treatment operations
    - Will the discharge permits be met?
- New Environmental Approvals:
    - Onus on the operator/owner to demonstrate adequate controls to manage any impacts due to insufficient buffers for both existing and proposed works
    - Heritage and ecological surveys may be required
- Planning:
    - Surrounding zoning may include sensitive land uses (residential) within recommended buffer distances.

On the other hand, some of these implementation issues can result in positive outcomes, including finding reuse opportunities for biosolids. The need for solids reduction is becoming increasingly evident as the volume of waste to landfill grows, while the available space for landfills shrinks. Biosolids produced as a by-product of the digestion process contain many nutrients required by plants for strong growth, including nitrogen, phosphorous, potassium and micronutrients. Therefore biosolids can be an excellent fertilizer for use in agriculture and forestry, and as a soil improver in composting. Adding biosolids to soil can improve water retention, help retain nutrients, accelerate plant growth, and potentially reduce stormwater runoff and erosion.

Auckland Council has adopted an ambitious aspirational zero waste target by 2040, with the intention to reduce curbside collection and waste going to landfill, while creating jobs and economic benefits (Jonassen Industrial Projects). Biogas production facilities provide the opportunity to meet this target, given that the desired waste streams are readily available and there is sufficient available land for such a facility.

There are also opportunities for funding and revenue generation at co-digestion facilities to improve payback. The most likely opportunities for revenue generation are:

- Large Scale Generation Certificates (LGCs)
- Revenue from excess electricity fed back into the grid
- Tipping fees for the acceptance of high-strength waste streams which can be equal to those charged at landfills.

Recent experience with these types of projects has found that the tipping fee is a very important parameter for reducing pay-back periods and increasing lifecycle savings. The availability of LGCs coupled with on-site savings from electricity and heat production also improve the cost-effectiveness of these facilities significantly.

6 EXISTING FACILITIES & LESSONS LEARNED

There are a number of facilities in operation globally which co-digest sewage and non-sewage wastes, including some which operate only on non-sewage waste streams. We have performed extensive desktop study and case study review of these facilities and have identified commonalities which are evident throughout facilities, both local and global. Some of the key lessons learned include:

- Facilities which have supplemented sewage sludge with non-sewage waste streams have all observed significant increases in biogas yield.
- The most effective waste streams for biogas production have high energy content. Examples include fats, oils, grease, cheese whey, abattoir waste, piggery waste, sewage sludge (from the earlier stages of the process), some forms of sugar wastes such as concentrated syrup or molasses, and food waste.
- The biogas produced from various wastes will vary in quality and sometimes requires treatment prior to combustion – this will reduce the risk of wear and tear on engines and equipment downstream, as well as increase co-generation system efficiency.
- The type of wastes used, the ratios at which each is fed into the digestion process, and the approach to collection, treatment and combustion of biogas, are all highly variable and site specific.
- The overall beneficial effectiveness of a biogas facility is multifaceted – the reduction of industrial waste, reduction of environmental impacts of the wastes, increase in renewable energy capability in a community, reduction of dependence on fossil fuels, reduction in fugitive emissions and general increase in process efficiency, are all positive aspects common to all case studies.

7 CONCLUSIONS / RECOMMENDATIONS

The beneficial utilisation of anaerobic digestion of various high-strength wastes for the production of energy, heat and other end products is a highly effective process that is increasingly becoming adopted around the world. There are an increasing number of small-scale wastewater treatment facilities worldwide that take advantage of the availability of high-strength wastes to benefit from increased biogas production. The additional benefit of heat and power generation, and subsequent reduction in environmental footprint and lifecycle operating cost, is an additional benefit aiding many facilities in meeting sustainability objectives. The co-digestion facilities also allow improved management of a second waste source, diverting waste away from landfills or separate treatment facilities.

The Yarra Valley Water case study demonstrates that:

- Co-digestion appears economically viable for existing and green-field facilities.
- The perceived need for pre-existing primary sedimentation and digestion unit processes for a positive codigestion business case is not always true. The cost of retrofitting these WWTP facilities to include primary sedimentation at the smaller scale may actually outweigh the benefit obtained.
- The use of HSWs such as fat-oil-and-grease (FOG) and food wastes, introduced to the anaerobic digester rather than to the headworks, combined with high-efficiency digestion and cogeneration

processes and HSW tipping fees shortens the project payback period and maximises the long-term financial and environmental benefits.

- It is important to perform a site-specific conceptual design to obtain a clear picture of the relative influence of the many factors that affect the results of the business case and minimize the project risk.

Based on these business cases, Yarra Valley Water is proceeding with implementing the co-digestion resource recovery facility and are leading the way in Australia in the municipal water company area.

The processes used and the waste streams fed into the system are well-proven at full scale implementation, and there are many examples of successful schemes from many perspectives including financial, social and environmental. Work continues at laboratory, pilot and full-scale developments to further optimise these practices and technologies; however there is general consensus that this is a highly beneficial technology that is likely to significantly increase over the coming years throughout the world.

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