DRIVERS FOR SUCCESSFUL WASTEWATER TO ENERGY PROJECTS

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ABSTRACT

CPG has been involved in wastewater treatment, product recovery and energy production from waste materials for more than 30 years, with more than 30 successful large scale wastewater to energy projects installed and operational around the world.

With the rise in environmental concerns, economic constraints, the increasing cost of resources, and the potential for supply limitations for energy, water and nutrients, it is now increasingly important to consider what value can be extracted from wastes, and how these products can provide positive economic and social outcomes for local authorities and businesses. It is a fact that waste to energy systems are being increasingly adopted in a number of areas globally, but CPG has found that the adoption of the systems hinges on different considerations in different regions, and for different industries and clients.

Based on CPG's experiences nationally and internationally, we discuss the different drivers we have identified in different locations, and for different markets. For example, many waste to energy facilities rely on the revenue from additional products such as fertiliser and carbon credits for their ongoing economic viability, where as others depend on regulatory subsidies.

We relate the experiences of CPG in numerous locations internationally. Using case studies we outline some of the key economic considerations that make energy from waste projects viable (or not viable). Using local and international experiences we examine the underlying factors that affect the economic viability. These factors include cultural considerations, environmental considerations, political considerations, economic incentives, risk management, and procurement options, and we consider the reasons why the uptake of these technologies is slow in NZ compared to other nations.

KEYWORDS

Economic viability, Carbon Credits, Anaerobic digestion, Internal Rate of Return, IRR

1 INTRODUCTION

Over the last 15 years there has been a significant change in the number of wastewater to energy facilities being developed and operated internationally.

Many anaerobic digestion facilities are moving away from tank based systems to lagoon based systems, which generally have lower capital and operational costs.

Over the last 10 years it has become significantly easier to access the national grid in many countries, and many nations have policies for encouraging distributed generation.

There have been increasing regulatory pressures for improved environmental sustainability, which has also lead to increased economic incentives for emission reductions and energy recovery.

At the same time globally there has been an increase in energy costs and a reduction in the security of energy supplies which have led to more focus from industrial companies on the possibility of cost reduction from waste to energy sources.

These changes have led to an increase in waste to energy projects being able to be undertaken on a cost justified basis. The wastewater to energy facilities that form the focus of this paper are industrial based wastewater streams that generally contain significantly higher concentrations of contaminants than domestic wastewater. CPGs experience has shown that these projects are typically projects implemented for financial reasons, with return on capital invested being a primary driver. During the development of the projects and in review assessment has been made into the primary drivers associated with the project economics. This paper examines the generic factors, their variation between regions and waste streams and then, reviews these in reference to New Zealand conditions.

The projects CPG has installed generally have an energy production of multiple megawatts, with the largest project presently capable of producing a gas energy output of around 50 MW. Many of these facilities are registered for Carbon Credits under the Kyoto protocol, with a number of the facilities reaching GOLD standard. Over the last seven years CPGs wastewater to energy projects have been responsible for mitigating approximately 5 million tonnes of CO_2 emissions.

2 FEASIBILITY OF PROJECTS

Feasibility of projects is typically measured in return on investment terms. Many projects are technically feasible, but do not reach the financial return on investment needed in order to attract the necessary finance from the factory owners or external investors.

Between 15 and 20% IRR (Internal Rate of Return) is considered the minimum threshold for most projects CPG have been involved with. Projects are typically either funded by industry themselves, or by third party investors. The third party investors typically use BOO (Build Own Operate) or BOOT (Build Own Operate Transfer) contract frameworks and set up specific project companies (SPC) for the investment, but also require a higher return on investment to compensate for the increase risk associated with the BOO, or BOOT contract framework.

Typical wastewater to energy projects take the wastewater and remove the carbonaceous pollutants converting these to methane suitable for use in boilers, cogeneration facilities, or compression systems for fuel production. Most wastewater to energy projects do not undertake post treatment on the waste as post treatment has a significant impact on the potential IRR.

2.1 FACTORS INFLUENCING FEASIBILITY:

There are numerous factors that influence the feasibility of projects. Many of the factors are based on the energy available from the waste stream. Whereas others relate to the cost associated with mitigation of issues associated with the process, or disposal of the wastes follow treatment.

2.1.1 WASTEWATER TYPE, STRENGTH AND CHARACTERISTICS

Wastewater characteristics have a significant effect on the feasibility of projects, critical aspects include:

- Flow rate
- Concentration
- Seasonality
- Contaminants
- Waste degradability
- Waste temperature
- Nutrient concentrations

General trends associated with wastewater include:

- More concentrated wastewater generically increases project viability.
- Increasing wastewater volume has a positive correlation with the feasibility of the project.
- Waste streams that are more readily degradable are generically more viable
- The longer the season the more viable the project
- More complex wastewater typically reduces viability due to increase operation requirements, or risk mitigation.
- Wastewater contaminated with other substances such as grit, plastic fibres or fibrous substances can affect the viability of a project.
- The temperature of the wastewater has an influence on the feasibility, CPG has been involved with projects where the temperature has been too hot, and similarly where the temperature has been too cold. Both scenarios have a consequential cost on the system which influences the feasibility
- Nutrients and micro-nutrients have an influence, both if there are not enough, but more particularly when there is too much. Nitrogen, Phosphorus, Potassium, Sulphur and salts all influence the viability of projects

Most of CPGs successful projects have wastewater that is ambient temperature in tropical locations, and have highly concentrated wastewater, with high mass load. Most projects have wastewater where nutrients are not limited and most projects have season longer than 200 days per annum.

2.1.2 ENVIRONMENTAL CONDITIONS

The environmental conditions have a significant impact on feasibility of systems. A number of aspects significantly influence the system cost these include:

- Ambient Temperature
- Local wind strength and direction
- Rainfall
- Geotechnical conditions (particularly groundwater and soil types)
- Treatment and disposal requirements for the wastewater following energy production
- Topography

General trends associated with environmental conditions include:

- Warmer climates have a positive influence on viability.
- Increasing wind speed has a small negative influence on viability
- Increasing rainfall has a small negative influence on viability
- Poor geotechnical conditions have a significant negative influence on project viability.
- Increasing treatment and disposal requirements have a significant negative influence on project viability.
- Increasing steepness of terrain contour has a significant negative influence on viability.

CPG has most of its facilities in tropical locations, because the physical environment allows systems to be designed and built without parasitic heat, which increases the available saleable energy. Most of CPG's existing projects are in locations with ground conditions suitable for lagoon construction and where the previous treatment facilities can treat the anaerobic effluent to the required standard without further capital investment.

2.1.3 ECONOMIC FACTORS

Economics justification is paramount the implementation of wastewater to energy projects. The economics are influenced by external factors such as environmental conditions or wastewater characteristics, but the direct economic conditions in the location of the project have a massive bearing on the viability.

Particular factors include:

- Cost of energy
- Availability of energy
- Ability to connect to national grids
- Availability of Green Energy incentives, such as Carbon Credits, ROCs, RECs, or feed in tariffs.
- Cost of labour
- Health and Safety environment
- Taxation rules
- Social environment

Generic trends associated with Economic factors include:

- Increasing energy cost has significant positive effect on viability.
- Increasing energy availability has a small negative effect on viability, but reducing energy security/dependability has a significant positive effect on viability.
- Green energy tariffs or emission reduction credits (incentives) have a significant positive effect on project viability
- Increasing ability to connect to national infrastructure has a small positive influence on project viability.
- Increasing cost of labour has a significant negative effect on the viability of projects.
- A more regulated Health and Safety environment has a moderate negative effect on project viability.
- At present increasing social interaction has a significant negative effect on project viability, despite positive social outcomes.
- Taxation rules have a significant effect on the viability and adoption of projects. In particular the ability to deduct operational expenditure but not capital expenditure leads to significantly reduced viability in some locations, particularly New Zealand.

2.1.4 REGULATORY FACTORS

Regulations play a role in feasibility, both positive and negative. The influences are often location specific as the environmental constraints that lead to regulation differ and therefore the regulations often focus on different parameters.

Particular regulatory factors include:

- Public consultation requirements
- Environmental discharge requirements,
- Distributed generation legislation

Generic trends associated with regulatory factors

- Increasing public consultation increases project costs
- Increasing environmental discharge requirements generally reduce project viability. This depends on how well the cost of providing alternative, non-energy generating, treatment facilities is considered in the evaluation of the project.
- Distributed generation regulations generally have a positive influence on wastewater to energy projects, although the effect can be small in some instances. If electricity can be sold at peak power price period then additional advantages can be achieved.

2.1.5 INFLUENCE OF LOCATION

Most systems are located in close proximity to the end user of the energy.

Location of the project makes a difference. The physical location in relation to the end uses of the energy is important.

CPG have not done a project where the energy end use or connection point to the grid has been over 5 km from the location of the project.

2.1.6 COST AND SECURITY OF ENERGY

The cost of energy is a significant driver in project feasibility, increasing cost of energy has a positive influence on project viability.

The unit cost of power has an influence on the viability of a waste to energy project particularly when the power is being sold to the national grid. Typically projects that sell to the national grid have a lower rate of return compared to those using the same amount of gas for heat energy or those producing electricity to avoiding purchasing electricity from the grid. The cost of producing energy from an electrical generation facility is higher per unit than energy burned in a boiler.

Gas availability and security of supply are factors that influence project viability.

CPG has been involved with a number of clients who have implemented systems in order to reduce the reliance on the national supply of electrical or fuel energy. In locations such as Argentina, the gas supplies are occasionally cut due to insufficient supply. These cuts require the industrial users to reduce or cease production, which has a significant effect on their business viability. Similarly in some locations in Europe dependence on the North Sea or Russian gas supplies has created economic issues for industrial users during period of supply constraint. In these circumstances the gas prices increases significantly, and can force businesses to cease operation.

2.1.7 CLIENT TYPE

There are a number of different clients and each has different parameters for project viability.

CPGs experience is that local government clients are willing to accept a significantly lower IRR for projects than industrial clients, and BOOT or BOO operators have higher required rates of return than many industrial clients

Most of CPGs clients for Wastewater to Energy projects are industrial or BOOT clients. Few local authorities have wastewater streams with high enough concentration to undertaken energy production.

2.1.8 TECHNOLOGY SELECTION

The design of anaerobic digesters technology has lead to the ability to increase returns through lower cost of construction, increased biogas yield and low parasitic energy demand. Reactors such as CPGs Cigar® technology have resulted in projects that can be used for a wide range of waste streams. The technologies have transformed anaerobic digestion economics and have resulted in many installations that would previously have been uneconomic.

Other technologies such as UASB and EGSB compete with lagoon based technology, but these high rate technologies require particular waste stream characteristics and are less flexible under many situations. They are however significantly smaller and are less affected by geotechnical constraints

3 CASE STUDIES

3.1.1 KHORAT WASTE TO ENERGY, NANKORN RATCHISMA, THAILAND

The KWTE project involved treating wastewater from a Cassava Starch manufacturing facility in Thailand, producing methane for boiler fuel and 3MW of electricity.

Table 1: Project parameter Khorat Waste to Energy

Project Parameter	
Flow rate (m3 per day)	9,600m3
COD concentration (mg/l)	27,000mg/l
Days operation per annum	300
Biogas use	Boiler and Cogeneration onsite
Geotechnical conditions	Good soil, no groundwater issues
Post treatment requirements	No post treatment required
Regulatory environment	Little regulatory pressure
Labour cost	Low labour cost
Climatic Conditions	Tropical
Nutrient issues	No nutrient constraints
Economic incentives	Carbon credits available
Project cost	$ 5 million USD
Internal Rate of Return (IRR) of project	108%

Principal Factors affecting feasibility for this project

Feasibility was reviewed by assessing the effect on Cost and Revenue if the factor being considered was changed by a set percentage.

The largest factors were Carbon Credits, followed by the seasonality of the waste. This had more significance on the project than the daily mass due to the size of the infrastructure requiring the same cost infrastructure but having less return. The next most significant factor was the mass load to the facility.

It was identified that all feed based factors with the exception of seasonality and concentration influenced the outcome in a predictable manner, however the wastewater concentration had an increasing influence with decreasing concentrations. But this was less important in tropical climates than the mass load of COD.

With lower concentration wastes as the concentration decreased the size of the facility would increase and therefore the cost for the facility increased, as did the operational requirements and the parasitic energy load for mixing and feed pumping. Due to the tropical climate parasitic heating load was not an issue.

Review of the project showed that in this instance the largest single factor influencing the project acceptance was the duration of the waste stream availability, if the season had been shorter, approximately 200 day per annum, then the return on investment would have reduced to approximately 30%.

This project was based on energy sales and at the time it was undertaken there was uncertainty around carbon credits, carbon credits were left out of the feasibility initially. Subsequently carbon credits added approximately 25% to the return on investment annually once they were approved.

3.1.2 INDONESIAN FEEDLOT PROJECT

This project was undertaken for a beef feedlot with 22,000 head of cattle. To make the investment viable the system was designed to provide the least capital cost technically feasible.

Table 2: Project parameters for Indonesian beef feedlot project

Project Parameter	
Flow rate (m3 per day)	600m3
Waste concentration (mg/l)	~6% VS
Days operation per annum	365
Biogas use	Flare only
Geotechnical conditions	Good soil, no groundwater issues
Post treatment requirements	No post treatment required
Regulatory environment	Little regulatory pressure
Labour cost	Low labour cost
Climatic Conditions	Tropical
Nutrient issues	No nutrient constraints
Economic incentives	Carbon credits available
Project cost	$0.75 million USD
Internal rate of return (IRR)	17%

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Review of feasibility:

This project was a highly unusual project for CPG; the client was a carbon trading organisation who undertook the project based solely on the carbon credits potentially available. The client accepted a return of below 20% per annum for the project.

The primary driver for the project was the carbon credits available, the waste stream being available 365 days per years and the low cost of the facility allowed the project to be feasible.

3.1.3 COMPARISON OF SUGAR CANE ETHANOL FACILITIES

Table 3: Project parameters for three separate ethanol facilities wastewaters

Project Parameter	Project 1 Thailand	Project 2 Brazil	Project 3 Australia
Mass load of COD (tonnes per day)	250	84	144
COD concentration (mg/l)	180,000	70,000	40,000
Days operation per annum	200	200	200
Biogas use	Boiler	Co-generation	Cogeneration
Geotechnical conditions	Good soil, no groundwater issues	Some rock encountered, higher berms required	Good soil conditions, partially bermed construction.
Post treatment requirements	Aerobic post treatment required. Disposal to land.	No post treatment required, existing disposal to land	No post treatment required, existing disposal to land.
Regulatory environment	Little regulatory pressure	Moderate regulatory environment	Strict regulatory environment
Labour cost	Low labour cost	Low to moderate	High
Climatic Conditions	Tropical	Tropical	Tropical
Nutrient issues	No nutrient constraints	No nutrient issues	No nutrient issues
Economic incentives	Carbon credits available	No Carbon Credits	RECs available
Project cost	$4.0 million USD	$2.0 million USD	4.7 Million AUD (estimated)
Revenue (revenue less costs)	$3.3 million USD/ annum	+.5 million USD/ annum	0.9 million AUD
Project IRR	47%	20%	13%
Project status	Implemented	Implemented	Declined by client

Review of feasibility:

The above assessment is as close as possible to assess different projects in different locations. The assessment shows that the combination of wastewater concentration, labour cost and energy end use, can have a significant detrimental influence on the adoption of wastewater to energy projects.

Two of the above projects were implemented while the third was not. The third project had increased costs relative to energy generated as a result of the lower waste concentration (increased size) size and higher labour costs for construction and operation.

3.2 SUMMARY OF FACTORS INFLUENCING FEASIBILITY

Over the past 3 years, CPG have examined 20 project opportunities, 15 of which were feasible and were implemented and 5 that were not. The general influences for parameter were summarised and are shown in Table 4 below:

Table 4: Summary of factors affecting feasibility

Factor affecting viability	Influence
Size of waste stream	Direct influence as a function of mass load, but adversely affected by reducing concentration. CPG have experience with project with up to 450 tonnes per day of COD. Larger projects have significantly improved economies of scale.
Length of waste season	Adversely affected as season length decreases. Construction costs stay the same but revenue reduces. CPG has experience reviewing projects with seasons from 6 week (viticulture industry, and corn processing, through to facilities that operate 365 days per annum. Our experience is that any duration below 180 days becomes difficult to justify economically.
Temperature of waste.	The temperature of the waste has little effect on the project cost between 25 and 40 degrees. Below 25 degrees parasitic load reduces the project viability, above 40 has a minor influence. The scale of the influence depends on the concentration of the waste, and the climatic conditions.
Nutrients	The effect of nutrients is the inverse of temperature, below a certain value there is a small cost implication; whereas above a concentration threshold of for example 3000 mg/l ammonia concentration the cost to the project is highly significant. An example is a facility that requires ammonia precipitation to reduce the Ammonia below approximately 3000 Mg/l, the cost of the facility added approximately 2.5 million capital cost to the project and increased operational expense by approximately 0.5 million per annum. In some case nutrient dosing may be required and the operational cost of this is a factor. Such costs can be mitigated in a nutrient rich waste source can be co-digested.
Climatic conditions	Climatic conditions are significant, tropical environments are the best with temperate climates requiring heating, and therefore reducing revenue from the project. Where waste streams enter the facility at high temperatures the influence of climatic condition is reduced. An example project in Netherlands requires a parasitic load of around 3MW to maintain temperature under winter conditions.
Regulatory Environment	The regulatory environment has a significant influence on projects, particularly in the planning, post treatment, and health and safety requirements. The cost of planning is very location specific. In Asia

	planning is very low cost whereas in New Zealand it can cost hundreds of thousands of dollars
Financial incentives	Financial incentives can have a very significant effect on the project viability. CPG have seen up to a 25% increase in revenue associated with Carbon Credits, and have been involved in one project that was solely undertaken for carbon credits. There are a variety of different incentive systems including Renewable Obligation Certificates (ROCs) in the UK, Feed in tariffs in UK and Germany, Renewable Energy Credits (Australia), but in NZ there are no available incentives.
Labour cost	Labour costs have a significant effect. The cost of construction increases significantly in high labour cost markets, as does the operational and the maintenance costs. The increased operational cost often has a significant effect on project viability.
Energy end use	Use of energy in a boiler or drier is the most cost effective use. Cogeneration systems are less cost effective, and electrical production without heat recovery is significantly less efficient. Selling power to the electrical grid is usually significantly less favorable than using electricity produced to reduce power purchased from the grid. This can alter with feed in tariffs, and RECs
Geotechnical conditions	Geotechnical considerations can mean a project is not viable. To date CPG has found the most significant influence for projects is high groundwater table, which requires the entire facility to be built above ground, or in tanks. Alternative technologies need to be considered under these circumstances.

4 WHAT DOES THE ABOVE MEAN FOR NZ

Having reviewed numerous facilities internationally, we considered these in context with the New Zealand environment.

It can be concluded that New Zealand is a difficult location for wastewater to energy projects for a number of reasons including:

- New Zealand company tax structures favour low capital cost, high operation cost treatment facilities.
- New Zealand industries generally have a high IRR requirement for new projects
- Many of New Zealand’s industries are seasonal.
- Low water costs mean that most New Zealand industries are high water users with resulting (relatively) low wastewater concentrations.
- Most New Zealand industries are relatively non polluting and so the mass loads are small compared to many overseas facilities. New Zealand has a temperate climate and so many of our waste streams require heating prior to digestion.

- New Zealand's regulatory environment is strict and environmental standards are high, often resulting in the need to undertake significant further treatment prior to discharge.

- The cost of labour is reasonably high in NZ.

- Energy prices are low to moderate, and few incentives are available to assist with projects viability.

These combine to make it difficult for projects to be economically viable in NZ. To date few anaerobic digestion facilities have been built outside of the local authorities. A number of those implemented projects have not been successful due largely to inadequate investigation and investment.

CPG was involved in a factory expansion project, which looked to be viable. The capital cost was about $2.5 million and the gas produced was worth about $0.7 million pa as boiler fuel replacement. The operational costs were about the same as the existing system. At a simple IRR of about 28%, CPG considered this would be acceptable. However, the client went with an aerobic treatment system, estimated to cost $1.8 million. This was because the additional annual operational cost for aeration of about $700,000 "could be written off against tax". The reduction in energy use both for the company and the country was not seen as having value in an accounting system. Waste treatment is seen as being a negative to a company balance sheet and the prevailing mentality seem generally to be "spend the smallest amount of capital possible".

5 CONCLUSIONS

Wastewater to energy projects are being implemented around the world for cost justified reasons. There are many drivers that influence the viability of these projects, and it has been found that the specific influence of the different drivers factors vary significantly between locations.

A number of factors have a significant influence on the viability. These include the environmental conditions, the geotechnical conditions, the size and seasonality of the waste stream, and the availability of incentives.

Most New Zealand industries are relatively efficient and so have small wastewater loads at low temperature. Our labour and regulatory compliance costs are high. As a result many facilities will struggle to attain a high IRR for a waste to energy project. However, there are a number of potential projects in New Zealand that would be regarded as viable if based overseas. New Zealand industry accounting appears to have a very short term focus, which along with taxation drivers, counts strongly against waste to energy projects and it is therefore likely that fewer systems will be viable in NZ than in many other international locations.

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