BIOSOLIDS DRYING AT CHRISTCHURCH WASTEWATER TREATMENT PLANT – A SUSTAINABLE SOLUTION

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ABSTRACT

Christchurch City Council has traditionally disposed of wastewater treatment plant biosolids by spreading on forestry land and more recently in rehabilitating a closed landfill. With both of these options operating on a limited timeframe Christchurch has had to develop a new strategy for biosolids management with a 20 year time horizon. The new strategy has been developed with a focus on meeting key Council objectives which include:

- Optimising biosolids reuse potential
- Minimizing carbon footprint
- Managing Council costs and risks
- Meeting social and cultural objectives

This paper explores sustainability themes in biosolids management and outlines the process involved in selecting and evaluating a preferred biosolids management option for Christchurch for the next 20 years. The main features of the option the council chose to implement, thermal belt drying, as well as some aspects of project implementation are described, including:

- A dual-line belt drying plant, designed and built by Klein of Germany
- An energy centre providing heat for the dryer, designed and operated by Energy for Industry
- Utilisation of 100% renewable fuels including landfill gas, biogas and wood
- Reuse of dried biosolids in mine rehabilitation
- Delivery through Design-Build and Design-Build-Operate Contracts

KEYWORDS

Sustainability, biosolids drying, design-build procurement processes

1 INTRODUCTION

The Christchurch Wastewater Treatment Plant (CWTP) comprises primary sedimentation, trickling filter solids contact process, secondary clarification and 225 hectares of oxidation ponds for disinfection prior to discharge through an ocean outfall.

Since the plant was commissioned in 1961, it has used mesophilic anaerobic digestion for sludge stabilization prior to dewatering and disposal. Biogas produced in the digesters is used in gas engines coupled to CHP units for electricity generation, and in boilers with heat recovery for sludge heating.

Digested biosolids are dewatered using two large Belmer belt filter presses. Historically the dewatered biosolids have been disposed to land, initially on farm land adjacent to the treatment plant. However, as biosolids volumes increased, and new limits on contaminant loadings for land application were introduced, the Council was forced to expand the land disposal regime to include council owned plantation forestry areas on the Canterbury Plains within 100km of the city.

These plantations were well suited to biosolids disposal, with a large land area available, good vehicle access for biosolids spreading, and some benefits experienced in the form of enhanced forest growth rates. In the mid 2000's two changes occurred forcing a rethink on the Christchurch biosolids management strategy. These changes and their impact on biosolids management at Christchurch are described below.

1.1 DRIVER FOR CHANGE 1: CLEARFELLING OF PLANTATIONS

The dominant land uses on the Mid-Canterbury Plains up until the mid-2000's were sheep farming and plantation forestry. With the introduction of new cost-effective irrigation technologies, including centre pivot irrigators, economic incentives were created in areas with available water, for large scale conversion of dryland sheep farms to irrigated dairy farms.

Large areas of the Mid-Canterbury Plains were converted to dairying between 2005 and 2008, including the forestry areas previously used for biosolids disposal. More marginal land continues to be used for forestry. However this is located in hill country with difficult access and is not considered viable for biosolids spreading.

With land use change driven by economic incentives, the forestry land previously used for biosolids disposal was no longer available, forcing Council to review alternatives.

1.2 DRIVER FOR CHANGE 2: NEW REGIONAL LANDFILL

A common alternative to disposal of biosolids to land in New Zealand is disposal to landfill. This approach is employed by several councils in the Wellington and Auckland areas. In the Christchurch case, a new regional landfill was in development by a consortium of local councils at the time that the existing land disposal scheme with under review.

The new landfill was to be run as a commercial enterprise by a company with shareholding spread between with local councils and a multi-national waste management company. Tipping fees of $NZ150/tonne or more were forecast for dewatered biosolids disposal. Furthermore the landfill operator had concerns about the stability of the new landfill and could not confirm that 100% of Christchurch biosolids could be accepted.

Review of the landfilling option by Council identified several concerns; firstly it could lead to $4M/yr in dumping fees, and secondly, it was not a secure alternative as there was no guarantee that the total quantity could be disposed by this route. The council decided to return to the drawing board and to develop a new biosolids strategy that was more cost efficient and more aligned with its sustainability policy.

2 DEVELOPING THE NEW STRATEGY

2.1 COMMUNITY CONCERNS FOR BIOSOLIDS MANAGEMENT

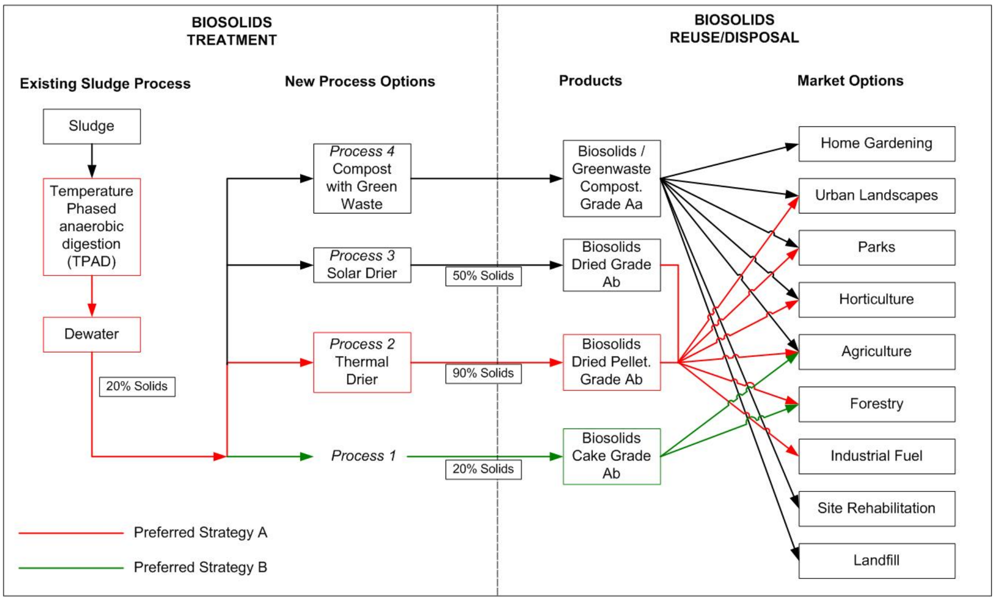
The first step in the new biosolids strategy revolved around a community consultation programme. Community consultation was externally facilitated and involved focus groups, from a number of sectors of the community using a Danish consultation methodology called "Scenario Workshopping". Feedback from the community and business groups involved in the workshopping process gave a clear directive to Council with the following themes emphasised:

- Energy generation from biosolids was a preferred management method
- Application to non-food producing land was acceptable, subject to removal of biological contaminants
- A balance between energy productivity and cost effectiveness should be achieved.

The themes identified made sense in the context of Canterbury regional economy. A predominant land use in Canterbury and a mainstay of the economy is food crop cultivation. Therefore land used for food cultivation should be protected from risks related to the application of biosolids. Energy generation from biosolids is a common sense objective, if this energy is available and can be extracted in a cost effective way.

Taking the consultation outcomes as a starting point, a multi-criteria analysis of a range of biosolids management options was conducted. The purpose of this study was to rank and rate various biosolids management options. A summary matrix of the options (SKM, 2006) is presented in Figure 1.

Figure 1: Biosolids Management Options Matrix



The multicriteria analysis of options led Council to focus on a shortlist of two biosolids processing options, namely solar drying and thermal drying. Factors in the shortlisting of these options were:

- Mixing biosolids with greenwaste to produce compost appears to provide numerous reuse options. However composting of biosolids was not favoured by the council
- Thermal and solar drying offered a good range of options for biosolids reuse (although further investigation found there are limitations with solar drying)
- The reuse options achievable by thermal and solar drying were compatible with the community aspirations as identified through consultation.

2.2 SOLAR DRYING OPTIONS

A number of relatively small scale solar biosolids drying plants have been built around the world in recent years including plants in Europe, Nicaragua and Australia (CH2M Hill 2007, IST Anlagenbau 2007). Solar drying is well suited to locations with a hot climate. Christchurch would be described as temperate rather than hot, and initial sizing of a solar drying plant for Christchurch based on modelling by IST Anlagenbau from Germany indicated that a solar plant for Christchurch would be the largest of its type in the world.

Low solar radiation in Christchurch in winter reduces water evaporation rates to low levels, pushing up the quantities of sludge needing to be stored. The resulting large drying hall was found to pose a significant odour risk. Solar drying also has limitations on dried biosolids dryness, with only 50 – 70% dry solids likely to be achieved. At this moisture level the biosolids are still biologically active and would be unlikely to consistently achieve "Grade A" standard under the NZ Water Biosolids Guidelines in terms of pathogen content in the dried product.

To boost the solar dryer throughput, heating options were considered. Council had landfill gas (LFG) available nearby that was being flared as part of a carbon credit agreement. The LFG could be used to heat the floor of the solar drying beds. Modelling, by solar drying plant vendors, predicted some improvement, however the drying halls are ultimately limited to about 60 tonnes of water evaporated per month per drying hall. With a minimum area required for solar drying of approximately 10,000 m^2 this still represents a very large and expensive system.

From the analysis outlined above it became apparent that the community expectation for biosolids to be applicable to land post drying would not be feasible due to risks primarily related to pathogen content. This option was taken no further and remaining investigations focussed on thermal drying.

2.3 THERMAL DRYING OPTIONS

From a wide range of technologies initially identified three thermal drying options were initially shortlisted:

- Drum drying
- Belt drying
- Paddle drying

Drum drying is a direct-fired technology, where the fuel combustion gases come into direct contact with the wet biosolids. There are two drum drying plants in New Zealand (New Plymouth and Lower Hutt) and both of these are heated using reticulated natural gas. As natural gas is not available in the South Island a drum dryer in Christchurch would need to be fuelled using diesel or Liquefied Petroleum Gas (LPG). These fuel options were not favoured for sustainability and supply cost risk reasons. Some of the preferred fuels, landfill gas and biogas, may be burnt in a drum dryer. However, corrosion risks exist that would require careful management as well as gas pretreatment.

Belt drying is emerging as a favoured drying technology at sites where waste heat is available, as it can operate at relatively low temperatures (Klein Technical Services, 2008). A significant number of small to intermediate-sized belt drying plants have been built in Europe in the last 10 years. A key advantage of belt drying is that heat is applied using a secondary fluid such as hot water or steam; this enables a wide range of fuels to be burnt in separate combustion units to produce the heat required. Corrosion risks are also reduced, as combustion products from "dirty" fuels such as landfill gas or biogas, do not come into contact with dryer itself.

Paddle drying was the third option investigated. Paddle dryers have the advantage of being indirectly heated, allowing a range of fuels, and are also capable of handling a wide range of sludge types. They are commonly used in Europe for contract sludge processing where varying sludge is transported to the drying plant from a number of suppliers (CCC Drying Plant Site Visit Report 2008). Paddle dryers are potentially subject to wear as the paddles rotate in close contact with bulk dry biosolids. This was identified as a particular risk in Christchurch with high silica content in the plant grit due to the sewerage network extending into coastal areas with sandy soils. Paddle drying may also pose higher safety risks due to dust generation within the process compared to other options.

Council investigations identified a range of risks and benefits for the shortlisted thermal drying options which are summarised in Table 1.

Table 1: Christchurch Drying Technology Risks and Benefits

Dryer Type	Benefits	Risks
Thermal belt dryer	- Dried biosolids is a fuel and is safe for land application - Well suited to LFG, biogas and wood	- Relatively high capital cost - High technology requires skilled operators but not as demanding as other options.
Thermal drum dryer	- Dried biosolids is a fuel and is safe for land application	- Not suited to wood fuel - High technology requires skilled operators - Conveyor/mixer abrasion due to high dried biosolids recycle rate
Thermal paddle dryer	- Dried biosolids is a fuel and is safe for land application - Well suited to LFG, biogas and wood	- Paddle abrasion and safety risks from dust generation - Relatively high capital cost - High technology requires skilled operators

2.4 ENERGY CONCERNS FOR BIOSOLIDS DRYING

Whilst Council was considering thermal drying technologies, it was also looking at energy supply options that would suit Christchurch. Thermal drying is energy intensive and subject to high operating costs. Christchurch City Council was looking for a solution that was energy efficient, met sustainability policies, and also utilised fuels that the council itself could supply. A preference for a multi-fuel heating system was established with the preferred heating fuels set as follows:

- **Landfill Gas** – available to Council and currently being flared to meet a carbon credit agreement

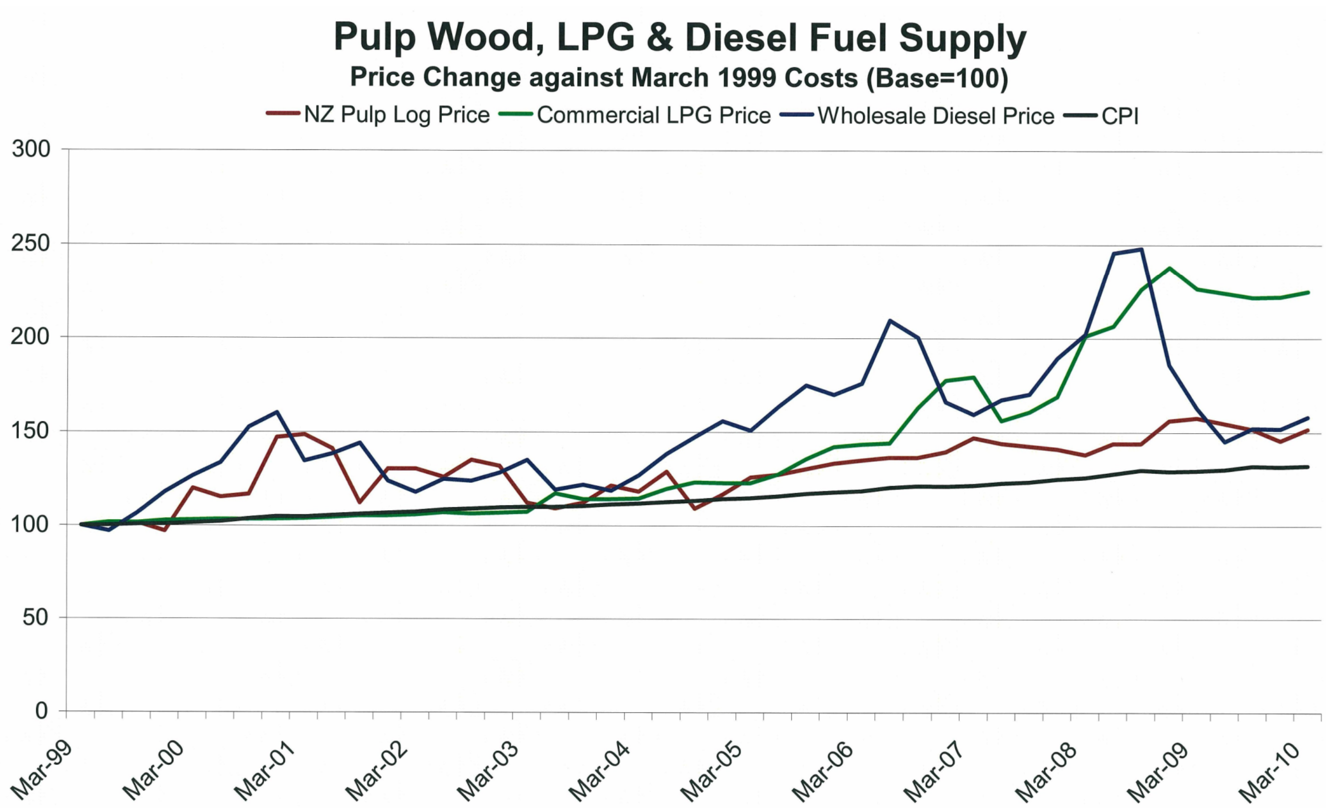
- **Digester Biogas** – produced at the treatment plant and currently used to generate electricity and heat, but with potential for gas yields to be improved to make gas available to heat the dryer

- **Wood** – readily available in the South Island to a consistent quality. Renewable, low sulphur fuel that can be burned cleanly using appropriate technology

- **Diesel** – not preferred for day to day use, but to be provided as a standby fuel should other fuels become unavailable for any reason.

Fossil fuels such as LPG and diesel were not preferred as primary fuels due to greenhouse gas concerns, as well as concerns regarding long term price stability. To investigate the comparative costs of fossil fuels and wood a model of New Zealand fuel supply costs over the last 10 years was prepared (data provided by NZ Statistics Dept, NZ Ministry of Agriculture and Forestry, 2009-2010). This is shown in Figure 2.

Figure 2: Supply Costs for Wood Vs Fossil Fuels in New Zealand, 1999 – 2010, on a per GJ basis



Wood fuel supply costs were found to have been more stable between 1999 and 2010 compared to fossil fuels. LPG and diesel show price variations of more than 50% in 2008 – 2009. These fluctuations could recur in the future due to supply and demand influences, creating economic risk for the project. Oil prices are forecast to continue increasing due to increasing demand in non-OECD countries and insufficient investment in exploration (International Energy Agency 2009).

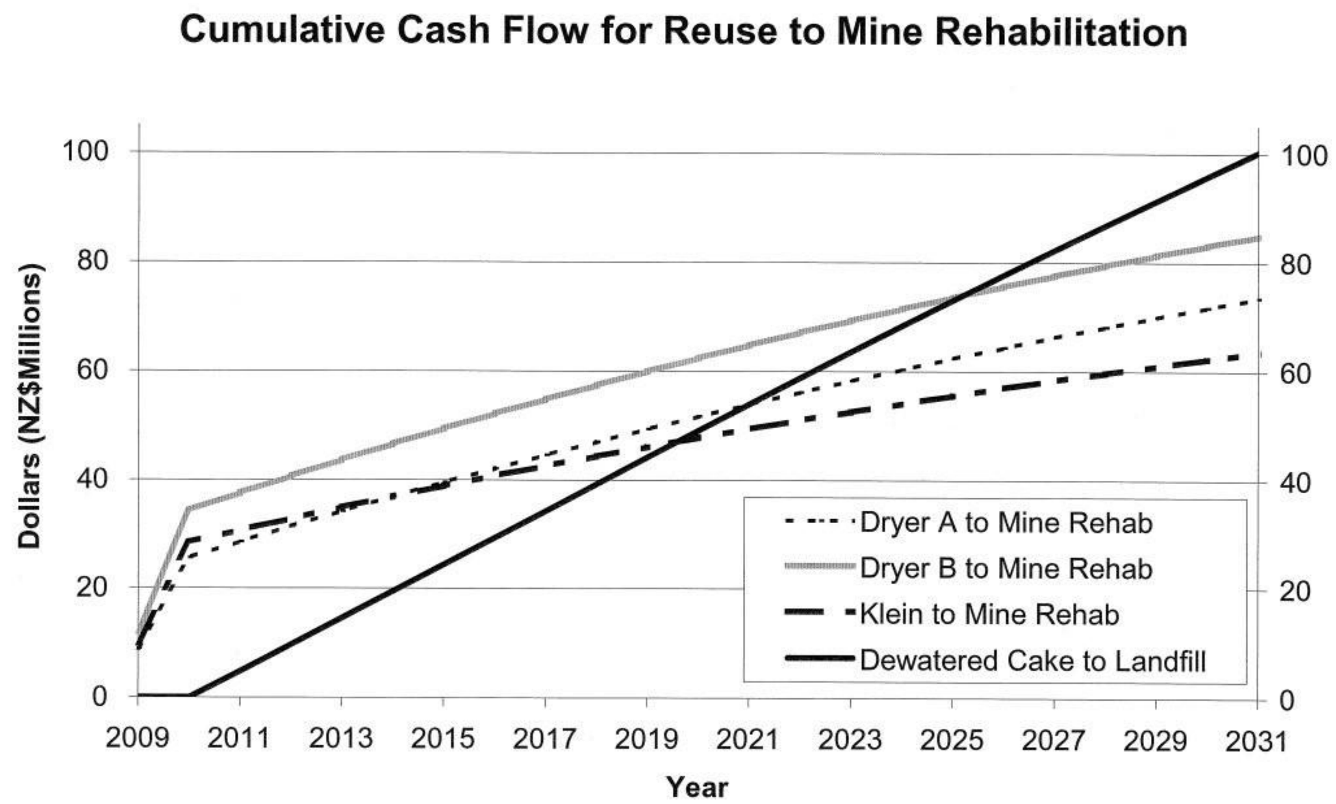
The multi-fuel heating system proposed for the Christchurch Biosoldis Drying Plant provides flexibility against a changing energy future, with the ability to change fuel as supply costs change, while maximising sustainability benefits through the use of renewable fuels.

2.5 DUAL LINE BELT DRYING OPTION

Belt drying was selected as the preferred option based on evaluation of economic and operational factors, and risks and benefits as outlined above. Net Present Value (NPV) economic analysis of the preferred drying option and a default option of continued discharge of dewatered biosolids to landfill was conducted in a spreadsheet model. A range of capital and operating parameters were entered into the model and sensitivity analyses were performed to test the robustness of modelling conclusions.

To assist with verifying the NPV model, site visits to drum drying, belt drying and paddle drying plants in the USA and Europe were conducted with the support of drying plant suppliers. Operators of drying plants were also interviewed by phone to gain an even spread of operator experience. Data obtained regarding plant downtime, maintenance labour and material costs, and the level of dedicated supervision required for each plant was loaded into the model. An example of the NPV modeling output shown as a cumulative cash flow curve is provide in Figure 3, comparing the cost–effectiveness of several drying optons with cake disposal to landfill.

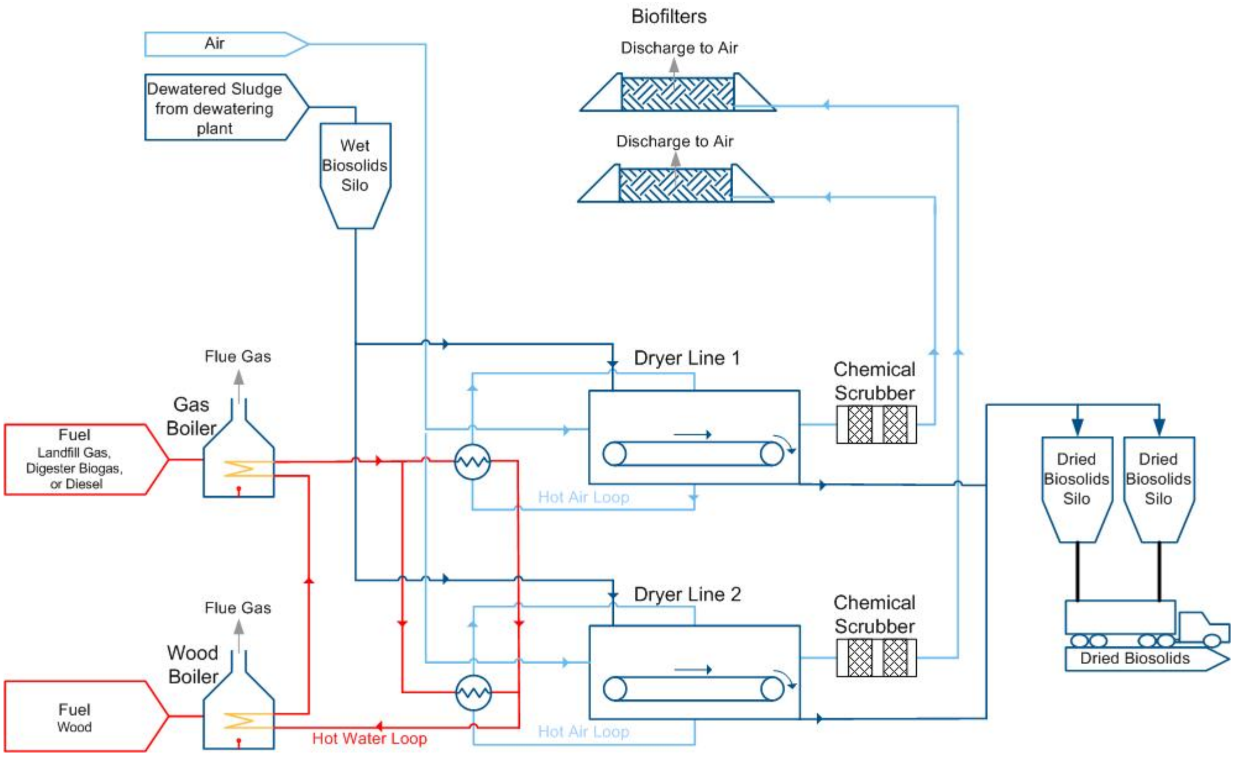
Figure 3 Comparative Cash Flow Curves for Thermal Drying and Disposal of Dewatered Cake to Landfill



The NPV model demonstrated that biosolids drying at Christchurch was economically viable compared to the "do nothing option" of continued disposal of dewatered cake to landfill. As well as providing a rationale for the project overall, the model was used as a decision making tool for the drying plant tender award process. For the Christchurch project the tender proposal submitted by Klein of Germany had the lowest 20 year NPV.

Based on NPV evaluation and other non-price factors, Klein was selected as the dryer supplier for Christchurch. Klein has supplied a number of biosolids drying lines in Europe and the UK and already has a presence in New Zealand as a supplier of belt filter presses. A schematic of the chosen drying plant configuration is provided in Figure 4 overleaf.

Figure 4. Schematic Diagram of Christchurch Biosolids Drying Plant



The chosen configuration for the drying plant consists of a dual-line belt dryer heated using high pressure hot water supplied by the energy centre. Each belt dryer units consist of a stainless steel enclosure 17m in length containing two rotating belts, one on top of the other. Dewatered biosolids are extruded onto the feed end of the top belt through a "noodlemaker", a stainless steel plate perforated with 8mm holes.

The noodlemaker moves back and forth across the belt to form a continuous layer of noodles up to 120m thick. The noodle mat moves along the top belt and then falls onto the bottom belt, returning to the feed end to emerge as dried biosolids. The noodlemaker design enhances drying performance by ensuring uniform size of noodles placed on the belt compared with belt dryers that use a screw conveyor to distribute the biosolids feed. Energy losses are also reduced compared to non-noodle technologies as the noodle mat is an open matrix through which air can pass with relative ease.

The dried biosolids discharged from the dryer are lightly crushed to achieve a bulk density of 500 kg/m^3 before being pneumatically conveyed to two 35 tonne dried biosolids silos.

The drying plant will process 72 tonnes per day of dewatered biosolids at 22% dry solids on average in 2010, to produce 17.8 tonnes of dried biosolids at 90% dry solids. This represents an average evaporative load of 2,250 kg of moisture per hour. Total evaporation capacity in the drying plant is 4,800 kg per hour. The drying plant has a guaranteed thermal energy efficiency of 2.95 GJ of energy utilized per tonne of moisture evaporated. Electrical energy efficiency is 52 kWh per tonne of moisture evaporated. Both of these efficiency ratings are at the high end of what is attainable with a range of biosolids dryer technologies.

The inside of the dryer is maintained at 130 – 150 °C by hot air recirculating through four air-to-water heat exchangers per dryer line. The energy centre provides high pressure hot water to the heat exchangers at 165 °C using two boilers with a net heat output of 4.5 MW each. This is sufficient for the maximum dryer heating demand to be met by either boiler operating on its own. The LFG for the gas boiler is supplied from a council network that serves a number of other users including the QEII Aquatic Centre, the Christchurch Art Gallery and Council Civic Building. As the drying plant is the lowest priority LFG user it will utilize gas at times of lower demand across the network, typically at night and during the weekends. The design of the energy centre allows for optimal use of the LFG by "soaking up" available gas not needed by other users and then adding additional heat from burning wood to meet demand for drying. By this method flaring of excess LFG will be minimised.

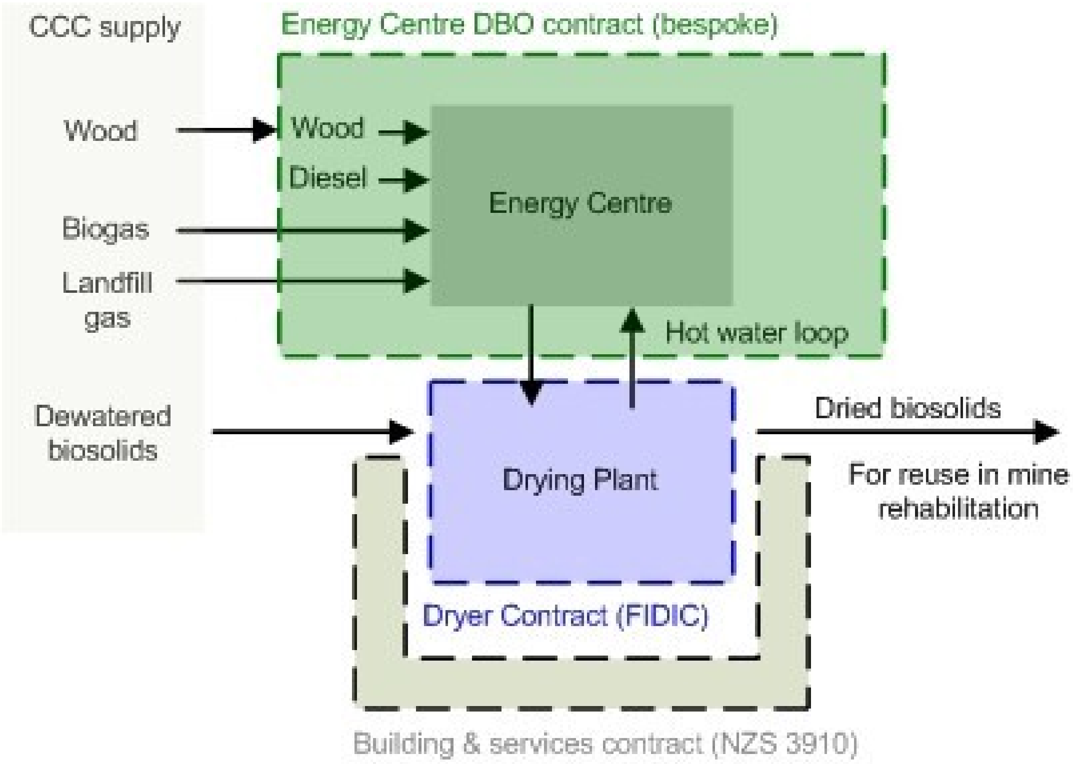
The dual line configuration provides for optimal energy efficiency as typical biosolids loads can be handled by a single line running at 90% capacity. This avoids the turn down problem with a single line that it would be run at less than 50% of capacity for most of the time, especially in the early years of operation.

Each dryer line has a dedicated odour control system incorporating a spray condenser, chemical scrubber and biofilter to ensure that odour emissions to air are minimal.

3 DRYING PLANT PROCUREMENT

Having established that the dryer project was economically viable a procurement plan for project implementation was developed by the council. The procurement plan incorporated three main contracts (Energy Centre DBO contract, Dryer contract, and Building and Services contract) as outlined in Figure 5.

Figure 5: Biosolids Drying Plant Procurement Plan



3.1 ENERGY CENTRE CONTRACT

Council had no experience operating large scale heating plant nor in managing a wood fuel supply logistics, and therefore wanted to transfer the design and operational risk related to the energy centre to a third party. The concern was addressed by using a Design-Build-Operate (DBO) form of contract to allocate responsibility to a contractor with experience in this area. Through a council tendering process this contract was awarded to Energy for Industry (EFI), a subsidiary of Meridian Energy, for 15 years duration.

The energy centre contract includes responsibility for design and construction of the energy centre including hot water reticulation system, as well as operation and maintenance and supply of wood fuel for a period of 15 years. Thermal energy is purchased by Council as hot water. Energy delivered is charged on the basis of $/GJ utilised with different charging rates apply for wood and gaseous fuels.

Within this contract landfill gas and biogas can be supplied to the energy centre by Council when it is available. The contractor is obliged to supply wood fuel to top up the heat supply to meet the energy demand. The overall quantity of wood to be supplied is notified to EFI at the start of each year, to allow time for procurement and seasoning of logs. The council also supplies wood to EFI from city tree trimming activities to be seasoned and chipped then supplied back to the council in the form of hot water. A fuel yard has been integrated into the drying facility to accommodate this option.

Photograph 1: Biosolids Drying Plant Energy Centre

3.2 DRYER CONTRACT

For the dryer contract package, Council wanted to encourage competitive bidding from a range of dryer suppliers – this required a focus on setting the essential performance standards, rather than prescribing the plant configuration in detail. The performance-based approach gave dryer vendors an opportunity to develop an optimal design for their respective technologies and the proposed duty.

The drying process package incorporated the process equipment including wet and dried biosolids transfer, handling and silos, the drying plant itself, a complete odour control system and all process electrical and controls work. Klein delivered the plant by sub-letting packages including the silo, mechanical handling systems and odour control package to specialist subcontractors also from Germany.

Photograph 2: Christchurch Biosolids Dryer Line 2

3.3 BUILDING AND SERVICES CONTRACT

The council decided that risks associated with dryer plant building and services could be managed by the council. The building, services and civil works were packaged together under a standard NZS3910 contract with project management and design services provided by CH2M Beca. This approach alleviated the drying plant vendor concerns about dealing with local building contractors and regulations, and also connecting to services on a site where they had no experience.

Photograph 3: Christchurch Biosolids Drying Building (Dewatering Building in Front)

4 DRIED BIOSOLIDS REUSE

Council has considered a range of options for using the dried granular biosolids that will be produced at CWTP and has worked with a range of other parties to develop reuse opportunities. Some of these are described below.

Dried Biosolids to Landfill

Council has looked closely at landfill disposal of dried biosolids. While this is not favoured, it is a considered a backup scenario if reuse options become problematic. NPV modeling by Council has confirmed that the drying facility is economically viable with the dried biosolids disposed to the Canterbury Regional landfill.

Reuse as fuel

Council is interested in developing the potential for biosolids to be used as fuel. However dried biosolids contains about 30% ash and is not suitable for combustion in conventional solid fuel boilers unless it is blended with other lower-ash content fuel such as coal.

Reuse as fertilizer

Reuse as fertilizer has been proven by New Plymouth District Council through their development and sale of "Bioboost" granular product from the New Plymouth Biosolids Drying Plant. Taking the New Plymouth example of successful reuse, Council has focused on finding viable reuse options and has recently finalised a commercial agreement with a third party mining company, to reuse dried biosolids for rehabilitation of large coal mine sites in the South Island.

5 CONCLUSIONS

Christchurch City Council has developed a Biosolids Drying Facility at the CWTP in response to external factors that impacted on existing biosolids disposal practices. Consultation with the community, together with reference to council policies, identified key features to be integrated into a new biosolids management strategy including:

- Energy generation from the use of biosolids as a fuel
- Application of dried biosolids to non-food producing land
- Flexibility to accommodate multiple renewable energy sources to mitigate fuel cost risks while achieving sustainability goals

To deliver on the council and community goals Council has constructed a dual-line belt drying plant, from Klein of Germany. The drying plant is heated by an energy centre using multiple renewable fuel sources.

In planning and implementing its 20 year Biosolids Strategy, Christchurch City Council has demonstrated that it is possible to produce Grade A Dried Biosolids using renewable energy and in a cost effective way. It has also developed a procurement approach that manages Councils risks by sharing them with third parties while capturing many of the economic benefits from the project.

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