USING BIOMASS AS A HEAT SOURCE FOR SLUDGE DRYING AT THE PARAPARAUMU WASTEWATER TREATMENT PLANT

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ABSTRACT

The Paraparaumu Wastewater Treatment Plant uses a thermal sludge drying process to produce a Grade 'A' stabilised biosolids. This treatment plant previously used a diesel boiler which provided heat via a high pressure hot water circuit to a rotary drum dryer. In 2008, the diesel boiler was identified as a) being a significant contributor to the overall carbon emissions for the Kāpiti Coast District Council and b) as having a high operating cost, particularly with rising diesel prices. Cardno BTO investigated alternatives by conducting a holistic biosolids options study, utilising multi-criteria analysis, that determined the best solution was the installation of a biomass (wood fuel) boiler to replace the existing diesel boiler.

A 500kW high efficiency reciprocating grate boiler supplied from Austria was installed in 2010, along with an associated fuel store and feed system. The boiler is capable of operating with wood chip, wood pellets, hogged fuel and other biomass. The new system has been an operational success, reducing sludge drying fuel costs by 50%, and reducing the Council's overall carbon emissions by 22% compared to 2007 levels.

KEYWORDS

Boiler, Thermal Sludge Drying, Biosolids, Biomass, Wood Chip, Wood fuel, Wood Pellets, Energy

1 INTRODUCTION

The Paraparaumu Wastewater Treatment Plant (WWTP) consists of a five stage Bardenpho nutrient removal treatment process that produces a waste sludge stream withdrawn from the Return Activated Sludge (RAS) produced in the clarifiers. The Waste Activated Sludge (WAS) is thickened in a Dissolved Air Flotation (DAF) thickening process from 0.8% DS to around 2.5% DS, dewatered in a decanter centrifuge to 18% DS, then dried in an indirect heat sludge dryer to approximately 75% DS. Dried sludge is stored in a skip bin that is taken off site for disposal.

The indirect heat sludge dryer consists of a hot water heater, cylindrical outer shell within which a rotor carrying a series of blades rotates. Sets of blades deposit the sludge against the hot shell in a thin film, while other blades remove the film and progress it along the length of the dryer. Heat is provided to the dryer through a closed loop high pressure hot water system. A high pressure centrifugal pump circulates water around the system at around 170°C and 9.5 bar. An arrangement of valves allows the addition of conditioners to maintain the quality of the water in the system. The expansion system uses nitrogen to maintain the hot water pressure.

The original system used a diesel boiler as the heat source for the hot water system (Photograph 1). The boiler operated continuously over a 24 hour period, for around 360 days of the year. It consumed around 438,000 litres of diesel per annum, at a cost (in 2008) of around $575,000. The Kāpiti Coast District Council (KCDC) identified the boiler as a high operational cost and source of carbon emissions for the Council.

Photograph 1: The Original Diesel Boiler

2 OPTIONS REVIEW

2.1 FEASIBILITY STUDY

The Kāpiti Coast District Council commissioned a feasibility study into the option of installing a biomass boiler to supply hot water to the existing dryer. The feasibility study determined that:

- The installation would reduce fuel costs from $575,000 (in 2008) by 50-80%.

- Biomass (wood chip, pellets, hogged fuel, and other woody products) are regarded as a low carbon source of energy, as the amount of CO_2 released on combustion is approximately equal to that which a tree absorbs while growing. Whilst not wholly carbon neutral, it is generally regarded as between 95% and 98% carbon neutral, depending on the scale of use and source of feedstock.

- Under the Communities for Climate Protection Programme, to which KCDC was a signatory, it had a target of a 15% reduction in CO_2 emissions by 2010 compared with a 2001 baseline. A review of 2007 data showed that emissions were actually increasing. The diesel boiler operation accounted for 1,161 tonnes of CO_2 emissions per annum. It was calculated the installation of a biomass boiler would decrease total Council emissions by 22%.

- The installation would be supported by EECA (Energy Efficiency and Conservation Authority), in the form of a $200,000 cash grant. In addition, an interest free Crown Loan of $995,555 with a 5 year term would be offered, providing considerable interest savings for the project.

- Biomass boilers are commonly used in Europe; modern boiler units of high quality and efficiency are readily available in standard designs.

- Financial analysis examining the installation of a biomass boiler showed it had the potential to save in excess of $8,500,000 over the 15 year predicted life of the replacement boiler plant.

2.2 BIOSOLIDS STRATEGY REVIEW

The Kāpiti Coast District Council, to confirm the decision, commissioned Cardno BTO to carry out a holistic biosolids strategy review. A number of options were considered, both by financial analysis and in a multi-criteria workshop. Multi-Criteria Analysis (MCA) was used to assess the economic, functional, environmental, regulatory framework, social, cultural, and risk aspects of each option. MCA is a methodology used to grade a number of different options based on qualitative and quantitative rankings for a number of different criteria. Each criterion has a weighting representing its importance, and each option is scored for each criterion. Following this, a sensitivity analysis changes the weightings for various criteria to determine if this has much effect on the result.

The review examined disposal methods of dried sludge and dewatered sludge (which would remove the need for the existing dryer). They included disposal to Council landfill, disposal to other regional landfills, beneficial re-use such as forestry application, in-vessel composting, and fertiliser production. The use of the existing boiler, a new biomass boiler, or a gas boiler were all considered under the dried sludge options.

The MCA process concluded that the best overall option for the Council was the installation of a biomass boiler, with disposal of dried sludge to the existing Council landfill. This confirmed the decision to proceed with the project.

3 TENDERING PROCESS

The project was split into two different tender processes, which were managed by Cardno BTO:

1. A ‘turn-key’ style contract for the biomass boiler supply and installation, including all associated works, based on NZS 3910 conditions of contract for building and engineering construction. This scope of

work included design, supply, installation and commission of a boiler unit, boiler house, fuel feed system, and fuel store.

2. A fuel supply contract, for 5 years duration (3+1+1 year), based on a product supply agreement.

3.1 BIOMASS BOILER INSTALLATION CONTRACT

The selected contractor for the biomass boiler installation offered a 500kW Binder step grate boiler manufactured in Austria (see Figure 1). It offered a high efficiency design, diesel burner backup, automated boiler control, tube cleaning, burn-back prevention and ash removal system. The boiler is capable of operating with wood chip, wood pellets, hogged fuel and other biomass and can handle moisture contents up to 55%. The typical operating efficiency of this combustion unit type is between 87% and 92%, depending on the load. As with all biomass boilers, wet fuel will inevitably reduce boiler efficiency and output as more energy is used to evaporate the water in the fuel.

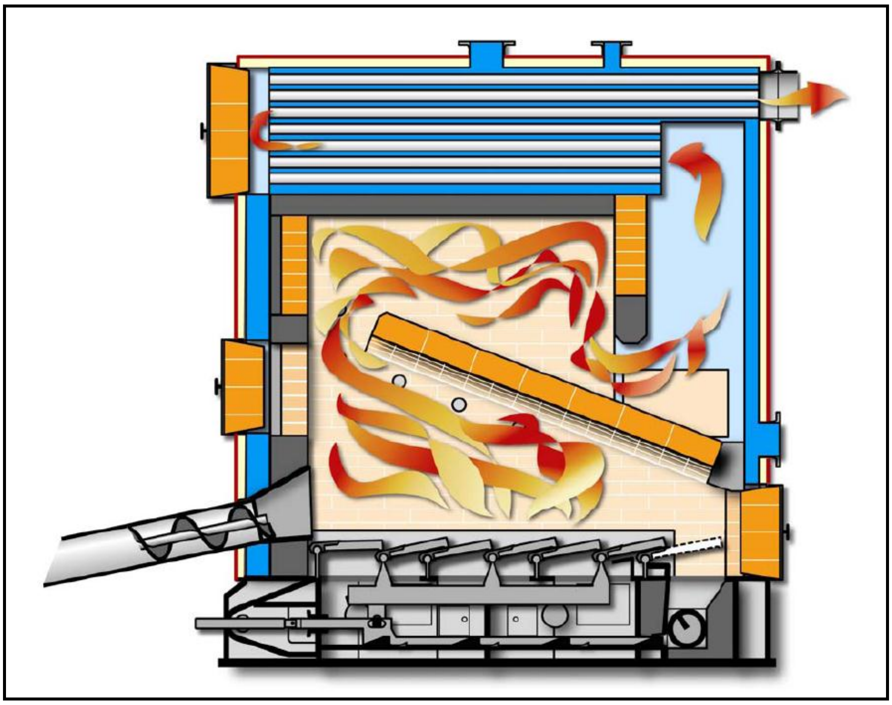


Figure 1: Schematic of Binder SRF-S Boiler (note, showing flat grate)

The combustion in the boiler happens in distinct stages. At full load, the main combustion chamber heats up to 800-820^{o}C, with primary combustion air being fed from below to promote a gasification-like process. Secondary air is then fed in higher in the chamber to create a rotation zone, this ensures efficient and complete burning of the volatile hydrocarbons which result from initial combustion.

The exhaust gases then make their way through the boiler unit, consisting of a water jacket around the expansion zone and a double-pass tube heat exchanger, giving up heat to the system water. This water jacket gives both an increase in overall boiler efficiency and a smaller system footprint. The exhaust gas is drawn through the system using an extraction fan. This fan is inverter driven, which allows it to exactly track the primary and secondary combustion fan air delivery volumes, and produce the optimum combustion profile at all operating capacities.

The ability to handle high moisture content is provided by the reciprocating step-grate system (Figure 2). The combustion chamber is effectively divided in half by a precisely designed radiation arch, constructed of high-temperature fire bricks. The shape and alignment of this arch evenly distribute radiated heat across the fuel pile. Initially, as the fuel enters the boiler, it begins drying, then combustion takes place, before burning out near the bottom. Ash from the process drops through the grate and is removed to a skip bin.

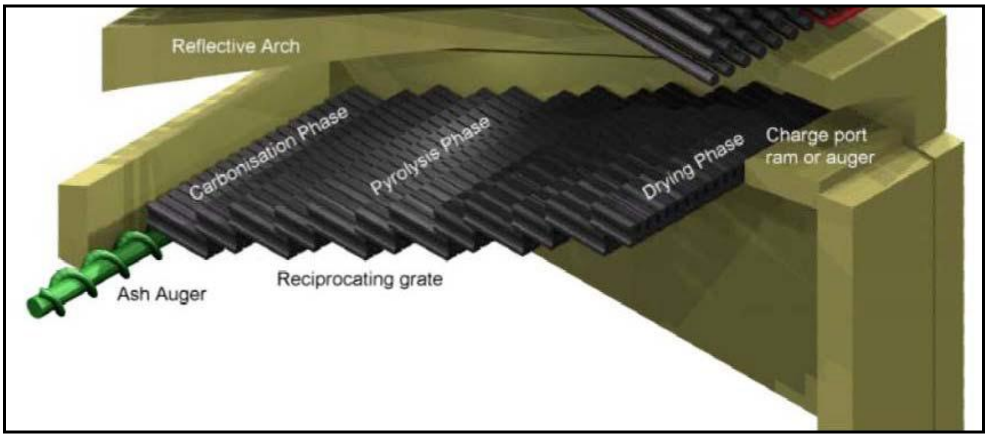


Figure 2: Schematic of Binder Step-Grate System

The boiler comes with a Comprehensive Visualisation Package (CVP) and PC-based graphic interface. The boiler maintains a set temperature of the water return to the dryer. If the dryer heat demand rises so does the boiler output to achieve the same temperature settings. Additionally, the system monitors O_2 levels in the exhaust from the boiler with a lambda sensor, adjusting combustion air feed to the boiler accordingly. This is done by adjusting the speed on primary and secondary air fans (both on variable speed drive). If the flue gas O_2 level is lower than the desired target for optimum combustion, it means too much fuel is in the chamber, so the primary and secondary fan speeds increase until the optimum O_2 level is achieved. Conversely if the O_2 level is too high, then there is insufficient combustion - i.e. more fuel is required. The system also provides increased efficiency by recirculating some the exhaust gases into the combustion feed air to keep the combustion chamber temperatures higher.

The boiler is fitted with both electric and diesel automatic ignition systems. The electric ignition system is normally used by KCDC since the fuel supply has low moisture content and will easily combust; the ignition system applies heat to the fuel to start ignition. If wet fuel sources were used, then the diesel ignition system can provide additional heat to get the boiler started.

The boiler also includes an automatic cleaning system for the heat exchanger fire tubes using high velocity air from the exhaust gas. This system maintains the high efficiency levels by using an oversized exhaust gas fan which is slowly brought up to full capacity at regular intervals for a few minutes. This high velocity air stream is redirected through the boiler tubes and removes dust deposits in the exchanger. The resulting ash is captured by an exhaust cyclone and deposited in the ash removal system.

Burnback prevention is provided in multiple forms. Firstly, the combustion chamber is operated under negative pressure. This effectively means that the combustion unit is constantly pulling air, and therefore flame, away from the point at which fuel is introduced. Secondly, there is an actuator controlled steel fuel barrier, or ‘burn-back flap’. This safety device is spring-loaded so that it always closes between pulses of fuel, effectively creates a fireproof barrier between the two augers, and preventing any burnback from reaching the fuel store. The spring-loaded mechanism also ensures that it fails closed in the event of a power failure. Finally, a thermostatic sensor on the stoker auger detects excessive heat and overrides the PLC routine. If a temperature of above 45^{o}C is detected, then the programming shuts down the fuel transfer auger and ramps up the speed of the stoker auger to push the remaining fuel in the stoker into the combustion chamber.

3.2 WOOD SUPPLY CONTRACT

The fuel supply contract was awarded to a wood pellet supplier. The advantage of wood pellets (Photograph 2) it is a consistent, reliable and high quality fuel. It has a low moisture content (less than 8% wet basis), with low ash content (less than 1%). The fuel is approximately 50% cheaper than diesel based on energy content.

Photograph 2: Wood Pellets

An advantage with the low moisture content of the wood pellet fuel is that it ensures high combustion chamber temperatures. In this particular application, odour air from the dryer were to be directed through the boiler to oxidise the odourous compounds, before processing in a wet scrubber system and exhausted to atmosphere via a stack. To ensure complete pollutant destruction, a temperature greater than 650^{o}C is required to be maintained in the combustion chamber. Furthermore, due to the high energy content, the wood pellets can be contained in a smaller containment area, and it is possible to deliver the pellets pneumatically into the fuel store.

It was found during the tendering process, that there is a lack of reliable source of wood chip in the lower North Island. However KCDC intends to undertake trials using wood chip in the future and encourage the formation of a supply chain for the fuel. It is generally accepted that if a local reliable supply chain can be established, then it will encourage other installations of biomass boilers in the area and reduce the fuel costs further. The boiler technology used and the design of associated fuel feed systems gives KCDC the flexibility to use different fuel types.

4 PROJECT PROGRAMME

The tenders were awarded in November 2009, and the total project took 10 months from kick-off to fully operational, which was as per the project schedule. Table 1 shows the main milestones and the dates that they were achieved.

Table 1: Key Milestones and Date Completed

Milestone	Date Completed
Tender Award	November 2009
Design Building Consent HAZOP	January 2010
Boiler Fabrication and Shipment Building Works	May 2010
Boiler Installation	July 2010
Commissioning	August 2010
Project Closeout	September 2010

5 DESIGN

The design consisted of a fuel store, walking floor, boiler feed system, ash collection system, boiler unit, and associated piping as shown in Figure 3.

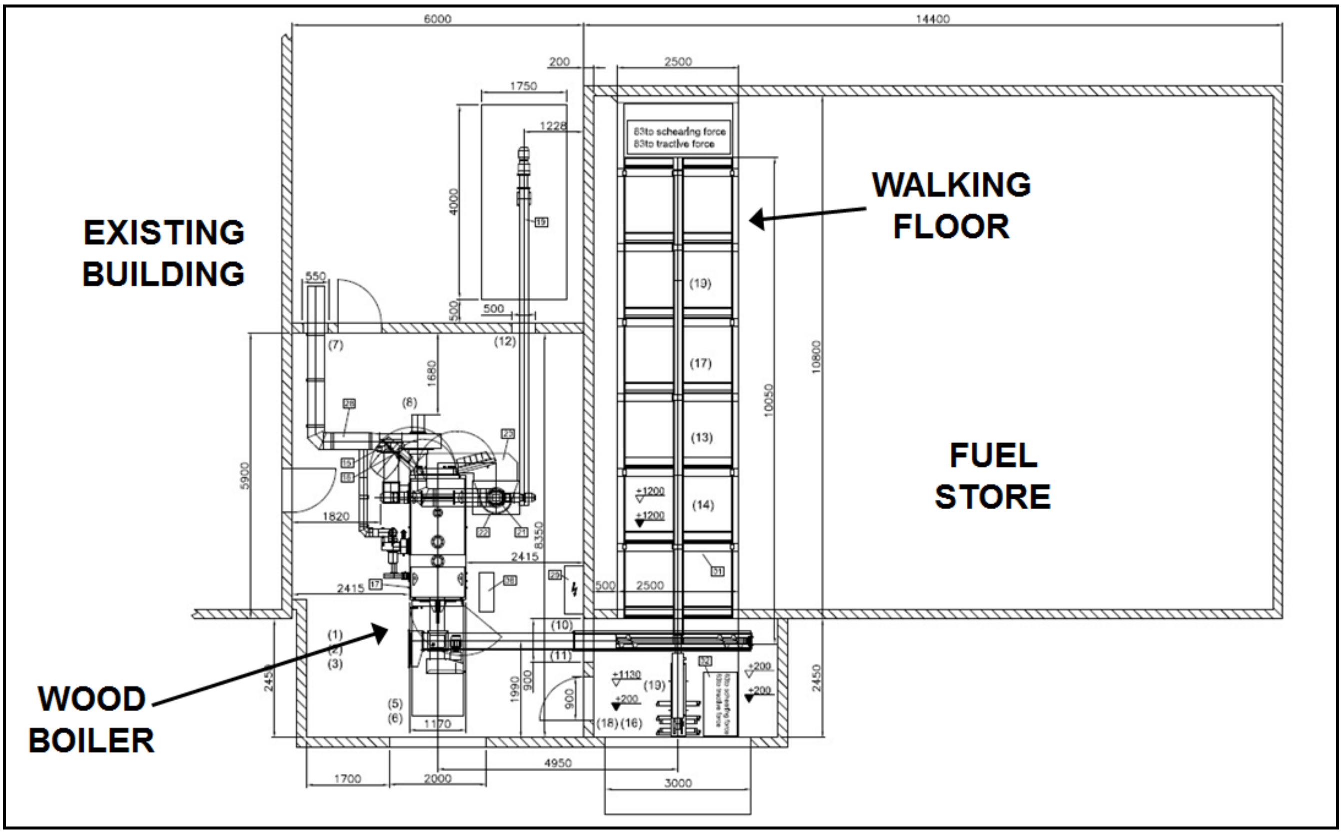


Figure 3: Layout of the New Biomass Boiler System

5.1 FUEL STORE AND FUEL FEED SYSTEM

The fuel store was designed with a footprint of 154m^2, capable of storing up to 400m^3 of woodfuel. This is sufficient for wood chip supply of 2-5 weeks depending on moisture content. The store roof height is compatible with a full size tipping truck. When using wood chip or hogged fuel, the fuel would be pushed up onto the walking floor utilizing a front end loader. The use of the wood pellets requires less storage volume due to its energy density, and it is easier to deliver pneumatically, therefore a removable enclosure was formed to store this type of fuel.

The walking floor measures 2.5m wide and is 10m long; is it powered by a hydraulic cylinder, which moves the wedge shaped steel sections back and forth. The system is robust, with the hydraulic driving ram designed to withstand a tractive and shearing force of 63 tonnes. The walking floor also eliminates any dead spaces where wet chip may degrade over time, which may cause loss of energy, and health hazard due to the growth of fungal spores.

The fuel from the walking floor falls onto a screw conveyor, which transports the woodfuel to a final feed conveyor which supplies fuel into the boiler. The conveyors are 330mm diameter, and capable of up to 100mm sized wood chip. Blockage switches are included which detect any blockage and shut down the conveyor to prevent damage. The walking floor and conveyors are all controlled by variable speed drive.

5.2 BOILER HOUSE

A separate boiler house was designed to contain the boiler unit detailed earlier in Section 3.1. The boiler measured 8.5m x 6m with roller doors to facilitate boiler servicing and also allows removal or replacement of the boiler unit if required in the future.

6 CONSTRUCTION AND COMMISSIONING

The construction of the building and installation of the boiler unit took place over approximately six months; project management was carried out by Cardno BTO. This included regular onsite meetings with the contractor and end client, design review, HAZOP facilitation, quality monitoring, contract administration, and problem solving. Cardno BTO liaised with the client, contractor, and other parties (sub-consultants, sub-contractors, suppliers) to achieve a successful outcome to the project, on time and on budget.

The construction took place in an area adjacent to the existing sludge dryer building. Photographs 3-7 show construction progress and the new boiler unit and fuel supply systems. The final electrical and piping interface connections were made during a tight two week shutdown period, as it was important to minimize any disruption to the normal plant operations.

The new boiler was commissioned in August 2010, with no significant issues. Photographs 8-9 show the plant in operation. The boiler has now been successfully in operation for three years, and is in operation 24 hours a day, for around 350 days a year.

Photograph 3: Construction underway adjacent existing Sludge Drying Plant

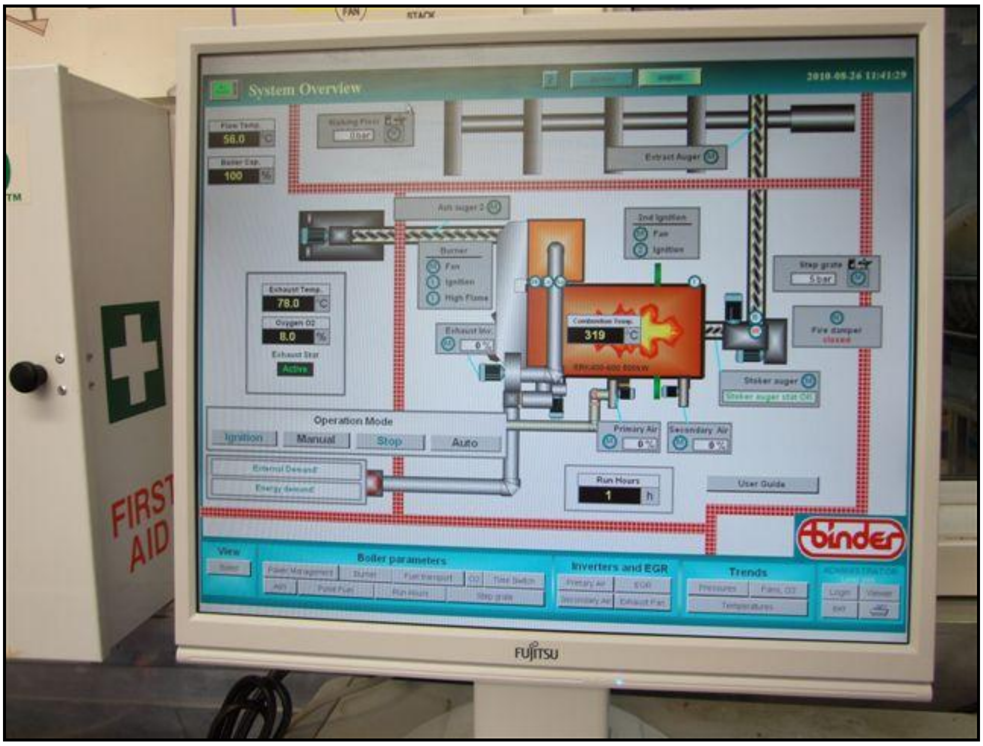
Photograph 4: Containment for Wood Pellets within the New Fuel Store

Photograph 5: Fuel Feed System to supply fuel to the New Boiler Unit

Photograph 6:   The New Biomass Boiler Unit

Photograph 7:   The First Delivery of Wood Pellets (Pneumatic System)

Photograph 8: The Boiler Combustion Chamber in Operation



Photograph 9: The Vendor Supplied Control System Interface.

7 CONCLUSIONS

The Kāpiti Coast District Council has reduced fuel costs by about 50%, and reduced the Council's total carbon emission by 22% (based on 2007 levels). The 500kW high efficiency reciprocating grate boiler, capable of operating with wood chip, wood pellets, hogged fuel and other biomass, supplied from Austria, was installed in 2010, along with an associated fuel store and feed system.

This solution was determined to be the best option for KCDC through a feasibility study followed by biosolids strategy review, under which a financial analysis and a multi-criteria analysis was used to assess the economic, functional, environmental, regulatory framework, social, cultural, and risk aspects of various options.

A robust tendering process ensuring the best technology was used for the application, and good project and construction management meant the project was carried out on time, on budget and to a high construction quality.

The boiler unit has now been successfully operating for three years and has been running on wood pellets since commissioning, this has proved to be a very reliable and consistent fuel type. However the Council is considering use of wood chip and other alternatives in the future to further reduce operating costs and support local business, the plant has been designed to allow this flexibility for KCDC.

This technology can be applied in many processes requiring heat; such as sludge drying, commercial heating, swimming pools, and schools. It offers a low fuel costs, reduction in carbon emissions and reliance on fossil fuels, and has been proven as a successful long-term solution for heat supply.

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3. Living Energy Ltd for the successful on time and within budget construction of the contract works.

4. Solid Energy Renewable Fuels Ltd for providing an ongoing reliable fuel supply for the boiler.