RENEWABLE BIOMASS FUEL R&D PRODUCTION FACILITY

Final Report

CONTRACT NUMBER:B/WM/00556/REP

URN NUMBER: 04/1601

dti

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RENEWABLE BIOMASS FUEL R & D PRODUCTION FACILITY

Project Number: B/WM/00556/REP
URN Number: 04/1601

Contractor
Fairport Engineering Limited

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EXECUTIVE SUMMARY

Project Objectives

The key objectives of the project and the research carried out were:

- To test the efficacy of the unique Fairport waste management process
- To produce enough biomass fuel products from the biodegradable element of Municipal Solid Waste (MSW) to enable appropriate trials for multiple fuel usage and industrial purposes to be carried out
- To identify and assess a renewable biomass fuel product that will be suitable for ROC's
- To identify markets for other biomass products that fall outside ROC's classification

Introduction and Background to the Project

Introduction

Three years ago the management of the Fairport Engineering Limited started to investigate the different ways of processing unsorted MSW. From the knowledge gained from this investigation they designed and built a small pilot processor to obtain data on operating parameters and product knowledge.

A key issue was to ensure the marketability of the principal output from the process: the biomass fuel fraction. Aware of the issues faced in the past in marketing RDF (Refuse Derived Fuel) Fairport took a pro-active route to addressing the problem. Instead of following the traditional route of producing an RDF and then finding outlets for the product Fairport instead started by developing an acceptable specification with potential customers for these biomass fuel products and only then set about developing the process which would provide products to meet this agreed specification.

The aim was to develop a process which could be flexible, cost effective and provide a proven and sustainable option for waste treatment whilst accommodating the following market dynamics:

- differing fuel product specifications and requirements for identified and specific end use applications
- evolving fiscal incentives
- changing market conditions
- evolving regulatory and statutory issues related to the management of MSW

- increasing pressure to identify fuels for power generation thus displacing some fossil fuel utilisation and mitigating net greenhouse gas emissions

A pilot plant was built and operated by Fairport and a decision was taken not to publicise any results from this facility until the process concept had been further verified in a scaled up demonstration facility.

With the operational, emissions and product data derived from the pilot plant exercise Fairport applied for a DTI Renewable Energy Research Grant to further expand and advance the production of a range of fuels from the biomass fraction found in MSW.

This application was successful so with joint match funding from the NWDA the project was given approval to start on the 7th August 2003.

The timetable for the project was as follows:

- Start 7th August 2003
- Build time December 2003
- Commissioning December 2003
- Operational Trials January – April 2004
- Decommissioning April 2004 to June 2004

Process Description

The basic plant configuration on the DTI demonstration plant project is split into four main stages:

- Waste reception and preparation
- Infeed and wet preparation
- Process and Primary Recovery
- Separation and Material Classification (Biomass Density Separator)

Waste reception and preparation

MSW by its very nature can vary in its size and composition. Refuse collection vehicles delivered MSW and off loaded into the plant where it was inspected manually and any unacceptable large items were removed (for example large pieces of metal, propane tanks, car batteries, furniture etc). All the remaining MSW was loaded into a trommel to separate the waste into two size fractions, + 150mm and –150mm.

The -150mm material was sent directly to the primary feed pile while the oversized materials (>150mm) were then fed into a shredder and once shredded to less than 150mm this material was mixed with the –150mm material to form a consistent input product to the process. The objective was to optimise the sizing of difficult elements in the waste such as textiles and to keep bulk densities within a narrow band. The sized waste was then loaded into a hopper and conveyed at a controlled rate to the wet preparation drum

Infeed and Wet Preparation

The pre-treated material was fed into the rotating wet preparation drum via a push floor feeder. A controlled amount of water was added to the waste via a weir above the push floor feeder to attain a moisture content of approximately 35%. Controlling the moisture content of the waste is a key requirement of the process for the following:

- to produce steam in the main processor to enable more effective sanitisation of the recyclable elements of the waste
- to attain a desired moisture content of the processed fuel products to assist with effective pelletisation and energy recovery
- to prevent dust from circulating in the vessels and thereby remove the potential for explosions
- to control the temperature in the downstream main processor which in itself enables drying of the waste to occur in a inform manner and assists in the controlled shrinkage of the plastic fraction

It is therefore important for the operators to have an estimate of the moisture content prior to the waste entering the wet preparation drum

The rotating drum uses a series of lifters and knives to break up and mix the waste and added water thoroughly causing the putrescible element of the waste to begin to break down, whilst steel and aluminium cans are cleaned and de-labelled (this improved quality makes the recyclables more marketable). This drum is 7mtres in length and 2.8 metres in diameter and is designed to handle 25000 tonnes per annum. The prepared waste progresses through the drum and is fed into the Fairport Main Processor.

Process and Primary Recovery

The patented Fairport Processor is a large rotating drum of approximately 13 metres in length and 3 metres in diameter. The prepared waste material is fed into one end of the drum and air heated by a gas burner is counter-currently along the drum creating a saturated steam environment inside the drum. This environment further breaks down the putrescible matter and cleans and sanitises other materials such as glass, cans and plastic bottles. As the material progresses along the drum moisture is driven off with the increasing temperature. **The process changes the physical and chemical state of the waste material.**

The temperature in the drum ranges from 80C at the inlet to approximately 200c at the exit and is at such a level as to prevent the occurrence of combustion reactions. Air is recirculated from the drum to provide combustion air for the burners.

During the process the increase in temperature causes some plastics to shrink. Two process fans circulate the hot air along the drum re-circulating approximately 70% of the airflow; the remainder is bled to atmosphere via an emissions scrubbing unit.

Both drums are maintained at slightly negative pressure. Any gases emanating from the process were extracted and passed through a wet scrubber to reduce pollutants (including volatile organic compounds – VOC's) to the required regulatory levels before being emitted to atmosphere.

At the discharge end of the Fairport Processor the dry processed product is fed into a rotating trommel and sized into two main categories, +50mm and –50mm in size.

It was found that approximately 35% of the infeed material typically migrates to the +50mm stream (as recyclable materials) where they can be easily separated using standard equipment such as magnets, eddy current separators and classifiers with inevitably some material sent to landfill.

Approximately 65% of the infeed material makes up the –50mm stream of products which constitute the unrefined fuel fraction. This fraction is further screened into 3 main sized categories: -5mm, +5mm to –16mm and +16mm to –50mm. The typical percentage split of the infeed material into each of these size ranges is approximately 30.8%, 23.1% and 11.3% respectively. Each of these sizes was then fed into the biomass density separation plant.

Separation and Material Classification

The Biomass Density Separator is a key component of the Fairport process and is responsible for refining the bioorganic fraction into a range of processed fuel products. It incorporates a range of standard material handling equipment including pneumatic conveying pipe work, rotary valves, cyclones, air filters, vibratory hopper and feed conveyor.

During the Project operations each unrefined product stream was fed separately into the density separation plant, which separated the light materials from the heavier ones producing a range of products. A suite of usable fuels and recyclates was produced ie fuel products, aggregates and plastics. The process can be varied to adjust the composition of the product ranges and further refinements can be made to suit individual end user requirements and specifications.

Results from the trials on the Density Separator indicated that the plastics content in the refined fuel product could be reduced to below 5% making it potentially suitable for use for example in co-firing applications. Approximately 14% to 30% of input could be converted to this fraction

Summary of Work Carried Out

This was the first time in the UK that a waste processing plant has been built, operated and licensed on a manufacturing facility which is not a permanent waste processing site. The Environment Agency issued a waste management licence to operate the demonstration facility treating mixed MSW for a period of three months. It was important that all legislative matters were properly adhered to and Fairport took the opportunity to investigate and implement all requisite environmental control procedures.

Strong support was received from the Environment Agency in the build up and application of the waste management license. This support and advice continued throughout the project with close liaison in developing the working plan and operation through the trials.

The plant was designed and built at the Fairport site in accordance with the design programme (August to November 2003) with operational trials commencing in January 2004 and concluding at the beginning of April with some 1000 tonnes of waste being processed through the plant.

During the trials the biomass density separation unit was developed to refine, separate and classify the various Fairport processed fuels and end products.

An extensive research programme was undertaken aimed at the production of empirical data related to all aspects of plant design (to assist in the development of the plant operating parameters and to minimise future technical and operational risks). Sampling and analysis of the material flow through the process and the production of large batches of samples for laboratory analysis took place throughout the trial programme. The feedback from the sample analysis was used to refine the process parameters and in so doing produce the required end products.

Extensive data was collected on plant operation and associated equipment settings, emissions, noise monitoring, waste management and costs. This information will assist in the design of future plants and in the setting of standards for this type of operation. The main parameters included:

- feed rate of waste
- moisture addition
- process temperatures
- drum speed
- air flow velocity

Once acceptable product specifications were achieved large samples of biomass fuel products were produced for testing for suitability as an alternative fuel product for power generation, gasification and use in industrial boilers such as in the cement industry.

Fuel samples of varying consistencies were produced, pelletised and stored to confirm the satisfactory pelletisation and storage capabilities of the biomass fuel products.

Markets for the range of Fairport products have been identified and evaluated. Bespoke products have been developed for a wide range of applications with the ability to tailor these to the individual client needs. This covers non-biodegradable recyclates (glass, plastic, ferrous & non-ferrous metals) and a range of Fairport biomass products for use as alternative fuels or processed aggregates.

Summary of Main Results

- The trials programme confirmed the process, operation, mechanical design and reliability of the plant and the capability to produce a range of new biomass products and recyclates.

- The designed throughput of six to eight tonnes per hour was achieved for a plant rated at a capacity of 25,000 tonnes per annum.

- New technologies and equipment for separating a range of biomass fuel products have been developed principally with the design of the Fairport Biomass Density Separator

- The energy usage during the trials was monitored and recorded. This information was used to confirm the forecast calculations on plant and equipment operating costs.

- Environmental data was monitored and recorded to confirm information for a future IPPC application.

- Emissions of VOC's from the process in the early weeks of operation exceeded the EA limits and action was taken in conjunction with the EA to reduce these emissions during the trials.

- Some 1000 tonnes of waste were processed through the plant and produced large batches of products for sampling and testing including laboratory analysis, co-firing tests with coal, gasification trials, and firing in a cement kiln

- Fairport commissioned an independent laboratory to conduct laboratory analysis on a large number of samples of the biomass fuel products. From this analysis data has been compiled to identify the composition of the fuel products and to assist in the classification of these fuel products
- The technical process to achieve the purity of the fuel products for compliance with the renewable obligation certification (ROC's) was confirmed in a number of focussed test activities (ie 98% purity by calorific value.) Analysis of the test results to date indicates that approximately 14-30% of the input feed material could be processed into fuel products suitable for ROC's. However more tests need to be carried out to confirm and improve the cost benefits of the exercise. From indicative analysis it is estimated that approximately 82 kwh of electricity and 209kwh of gas would be required to process one tonne of input into the range of products

- Renewable fuel products that do not qualify for ROC's have also been produced, ie for cement kiln firing and use in industrial boilers.

- The biomass fuel products were successfully pelletised without the use of added binders or moisture. This increased the bulk density from 180kg/m^3 – 200kg/m^3 to 600kg/m^3. The biomass fuel pellets were satisfactorily stored for long periods of time (10-12 weeks) without further reaction or activity.
- The trials programme has successfully demonstrated the production of a range of biomass products that have been presented to the power generation industry test facility at Ratcliffe (Power Technology Ltd) for assessment of suitability of use as an alternative fuel to assist the generation industry obligations. Trials on co-milling and co-firing refined renewable biomass fuel (RRBF) for use in a utility boiler are very positive confirming that the RRBF is suitable for this purpose. Further investigations in respect of EA regulations are still to be completed.

- Trials using the RRBF as a fuel for gasification proved successful, with the production of a suitable gas for use with a gas fired internal combustion engine.

- Trails on the use of RBF as an alternative fuel for the use in cement kilns have proved successful and confirm suitability for this purpose.

- Potential markets for the range of new biomass products and recyclates have been identified. The range includes biomass fuel products, ferrous and non-ferrous metals, plastics, glass aggregates and textiles

- A comparison of the Fairport Refined Renewable Biomass Fuel products with other similar fuel products has been compiled

Conclusions

- The Project successfully proved the efficacy of the newly developed Fairport process and equipment and made significant progress on proving the suitability for the new biomass products for use in industrial applications.

- The development of the Fairport Biomass Density Separator is a major step forward in the refinement of products to meet individual end user specifications. It was fundamental to the success of the project in satisfying stringent legislative and market requirements. It can be seen from the results of the trials that the separation processes removed the vast majority of heavy non combustible items for re-use as other products, together with further refinement resulting in the removal of varying amounts of impurities and plastics from the end products. Further development of a full sized separation plant will provide opportunities for major steps forward in the production of refined fuel products .

- Major progress was made on the control of emissions and odours. Extensive monitoring of emissions to the environment and in the workplace was carried out. The volume of VOC's generated proved to be an unexpected issue and future plant designs will incorporate revised emissions scrubbing units that Fairport are confident will remove the VOC's and odours problem.

- Data has been collected from the programme to assist in the classification of the fuel products for Renewable Obligations Certification. The programme has proved that the Fairport biomass fuel products can be refined to meet the current standards on purity.

- The development of a range of biomass fuel products will divert significant volumes of biodegradable material away from landfill thus meeting EU and Government targets.

- A detailed environmental impact assessment has been produced and issued covering site, process, and products.

- Tight control of the deliveries, dispatching and weighing of consignments of waste was essential and proved invaluable in the administration of the project on waste management and control.

Recommendations

- During the trials programme a number of designs were modified to improve process efficiency. This covered modifications to chutes, hoppers, conveyors, and feeders, drum internals and seals. All these points are to be incorporated in future plant designs.

- The plant constructed at Adlington was a full size single process line designed to process 25,000 tonnes of waste per annum. The design is flexible and modular and facilitates capacity increases via the provision of additional processor modules. Fairport recommends this flexible approach which will make future capacity extensions relatively simple and cost effective.

- It is recommended that the further development of the product markets be carried out and that this will be a prime objective supporting future business proposals.

- The trials programme has successfully proven the capability to process waste, produce a range of RRBF and recover other materials for recycling. A further opportunity to develop the plant and process to a full sized commercial operation to demonstrate this to the Waste Industry and UK Government is now required.

- Fairport recommends that the development of a sustainable RRBF product presents an opportunity of meeting with Government to review and revise policy and set new standards for renewable energy and waste management issues and that this will be best pursued through the formation of a dedicated trade association and Fairport is currently in discussion with other companies in the sector to establish such an association.

- The trials programme is seen to be very successful in :
  - achieving the key objectives of the Project
  - proving the capability to effectively process waste
  - producing a range of new biomass fuel products
  - recovering materials and recyclates to help recycling targets
  - proving the capability to divert waste from landfill

- Fairport strongly recommends that the plant and process be developed further to demonstrate its unique capabilities to assist the waste sector and the UK Government to meet its waste targets and strategies whilst also providing a potential alternative fuel source to assist with meeting targets and strategies in the energy sector

CONTENTS

Glossary of Terms

BMW	Biodegradable Municipal Waste
CDM	Construction Design Management
COSHH	Control of Substances Hazardous to Health
DEFRA	Department of Environment Food & Rural Affairs
DTI	Department of Trade and Industry
EA	Environment Agency
EIA	Environmental Impact Assessment
Energy Balance	Details the energy used by or calculated use of the process plant and equipment
FES	Future Energy Solutions
HSE	Health & Safety Executive
IPPC	Integrated Prevention of Pollution & Control
Mass Balance	Details of the mass flow through each section of the process plant, showing the amount of material in each stream
MSW	Municipal Solid Waste
NWDA	North West Development Agency
R & D Trials Plant	Research & Development Trials Plant
RBF	Renewable biomass Fuel
RRBF	Refined Renewable Biomass Fuel
ROC	Renewable Obligations Certificate
VOC's	Volatile Organic Compounds
WID	Waste Incineration Directive

1.0 INTRODUCTION

Environmental issues are taking centre stage at the highest level in Government around the world. The rapid pace of change in the waste management industry is being led by EU and UK Government legislation which is imposing increasingly onerous targets on local authorities and businesses. To achieve these targets local authorities are looking outside the traditional methods of waste disposal such as incineration and landfill and are embracing new technologies which apply the benefits of traditional proven process and materials handling techniques to the handling and sorting of waste.

Over the past three years Fairport Engineering Limited has used its extensive experience in the materials handling and process engineering industries to develop a process which will take 100% of a local authority's household waste, process the waste **without incineration** and leave only approximately 15% to be landfilled. The first 25% of the recovery through the process represents pure recyclable resources such as metals, plastics and glass whilst a further 15% is water recovered for re-use in the process.

The remaining 45% is the residual biodegradable material in the input waste comprising food, paper and green wastes. This is converted by the process into a range of renewable biomass fuel products for re-use and for which very important markets have been identified in the power generation and cement industry where they can be used to meet the Government's alternative to fossil fuel initiatives.

The diversion of this biodegradable material (which produces methane) is at the heart of the EU Landfill Directive and reductions in the volume of waste sent to landfill is of particular benefit in the North West where available landfill space is rapidly decreasing.

Tough targets have been set on local authorities:

- Recycling
  - 25% Municipal Solid Waste (MSW) to be recycled by 2005
  - 50% Municipal Solid Waste to be recycled by 2010
- Landfill diversion
  - 75% of the 1995 volume by 2006
  - 50% of the 1995 volume by 2009
  - 35% of the 1995 volume by 2016

In addition the UK Government is addressing its commitment to reducing emissions from industry by introducing targets for the reduction in the levels of fossil fuels being used, for example in the power generation industry. By its Renewable Obligations Certificate scheme it is targeting a level of 10.4% fossil fuel alternatives use by 2006 and this has led to a growth in demand for biomass fuel products. Many of these are currently imported and do not provide long term sustainable solutions.

The range of Fairport renewable biomass fuel products will provide a sustainable renewable energy source which will be a cost effective and more environmentally friendly alternative to carbon fuels and other (imported) biomass fuels.

Fairport considers that its proposed process and range of products will help the UK Government to meet its targets for recycling, landfill diversion and use of non fossil/biomass fuels.

The dates for the Government targets on recycling rates and non carbon fuel usage are fixed and coming ever closer. It is therefore important that solutions are found quickly and the Project will help accelerate these solutions

2.0 PROJECT AIMS AND OBJECTIVES

The Project aims and objectives were defined as follows:

- To design, build and install a full size experimental test rig

- To produce sufficiently large batches of the new biomass fuel products to enable appropriate trials at power generation and other industrial user's test facilities (and additionally to trial in the light aggregates industry both as a fuel and a process ingredient)

- To identify a renewable biomass fuel from cellulosic fines (biodegradable waste material) which will be suitable for ROC's and to carry out appropriate test work to prove compliance with ROC requirements

- To identify other renewable biomass fuel products which may not qualify for ROC's but have recognised and sustainable industrial applications

- To investigate secondary markets for the new biomass fuel products, for example, via gasification

- To further develop new techniques and equipment for separating a range of biomass fuel products and improving quality through the development of appropriate glass and heavy particulates removal processes and equipment. Included herein will be a range of screening, pelletisation and coating tests designed to remove odours, increase bulk density and strength, thus increasing easy of storage and handleability.

- To determine the technical and environmental criteria of the new fuel products and the associated production process (including a full Environmental Impact Assessment)

- To compare the calorific value, ash content and gas emissions levels of the new Biomass fuel products with other biomass fuels and to compare the benefits of using these products with established fuels such as coal (including operational benefits, emissions and ease of use)

- To research the marketplace requirements for renewable biomass fuel products and to identify and pursue the appropriate routes to market

- To comply with the DTI Technology Route Map on renewables by extraction of the biodegradable components of municipal (household) waste

The key activities on the Project were clearly defined in the contract documents and we report here against the designated headings in the contract.

3.0 KEY ACTIVITIES AND OBSERVATIONS

3.1 Design, Build and Commission R&D Production Facility

The design of the facility was based on two main factors – the experience gained from development work carried out on the previous small scale pilot plants and the knowledge gained from discussions with potential end users of the Fairport Biomass Products as to the required specification of these products. Fairport used all of its unique process engineering expertise to produce not only a process and system which would 'scale up' the previous plants to a full sized single processor capable of treating waste using the 'Fairport Process' but also a process which having recovered recyclable items (glass, metals, plastics) would then convert the residual biodegradable municipal waste into a range of usable and saleable biomass products. This initial design exercise took 6 weeks to complete. Due to the experimental nature of the Project it was necessary over the ensuing months to undertake a variety of new design developments and re-designs of existing features.

The first major deviation from the original design intent was determined by a lack of available space. Instead of carrying out the front-end reception and sorting of waste in the Adlington facility it was decided to transfer this activity to another location close to Adlington. The untreated waste was received at this second location, sorted and mixed, sized, shredded and delivered to Adlington as a prepared product ready for feeding into the process. Further detail on the operational aspects of this change will be provided later in this report.

Similarly since the focus of the Project was on proving the suitability of the end products (the Fairport Biomass products) it was decided to ensure maximum space was available for achieving this aim that all other products (known as the +50mm) were diverted to another location for mechanical separation. This fraction comprised mainly plastics, metals and textiles and for a period was sent to landfill as focus was made on the separation of the biomass products.

One of the benefits of the Fairport process and equipment is that it applies technology proven in other industry sectors into a new sector, waste management. Accordingly many of the proprietary items such as push floor feeders, screens, trommels, shredders and conveyors were obtained from long standing specialist equipment suppliers. To save costs most of these items were hired in for the relatively short duration of the Project.

The Project was housed in an existing industrial building in Adlington occupying 22000 sq ft which was specially prepared for this Project. The concrete floors and drains were sealed, as were any gaps into adjoining buildings. To ensure that Fairport's proud Health & Safety record was maintained the electrical installation was checked and where appropriate replaced or upgraded. A weighbridge was hired and installed and a manned gatehouse was provided. The whole facility was formally registered as a CDM site with the HSE during the construction phase.

Recognising the relatively short duration of the Project a decision was made to hire propane gas tanks and run the plant on propane rather than natural gas. This saved the additional costs of installing a natural gas supply. Over the short term of the Project this was found to be cost effective but on longer term Projects natural gas will be provided. Similarly the electricity requirements were such that an increased supply capacity to the site was needed. Because of the long lead times and associated costs of the electricity supply a decision was taken to use a generator to provide ‘top up’ electrical requirements.

All the process system controls were designed by the Fairport in house specialists and the eventual plant could be operated by a single operator from a lap top computer in the purpose built control room. CCTV was installed around the process equipment and inside certain items to give the operator maximum visual control.

The majority of the structural steel supports and the major processor drums were designed, manufactured and installed by Fairport. These drums were full size with the main processor measuring 14 metres in length and with a diameter of 2.8 metres. In addition sundry chutes, hoppers, ductwork and piping was manufactured and supplied by Fairport.

Included in the design of the facility was a range of environmental control equipment including odour controls, noise abatement, emission control equipment and dust/plastic film filters.

Overall the system and equipment worked well but attached in Appendix A is a matrix detailing where improvements were made to individual items of equipment or where re-designs will be necessary on future plants/facilities and suggestions for the design of features on future plants.

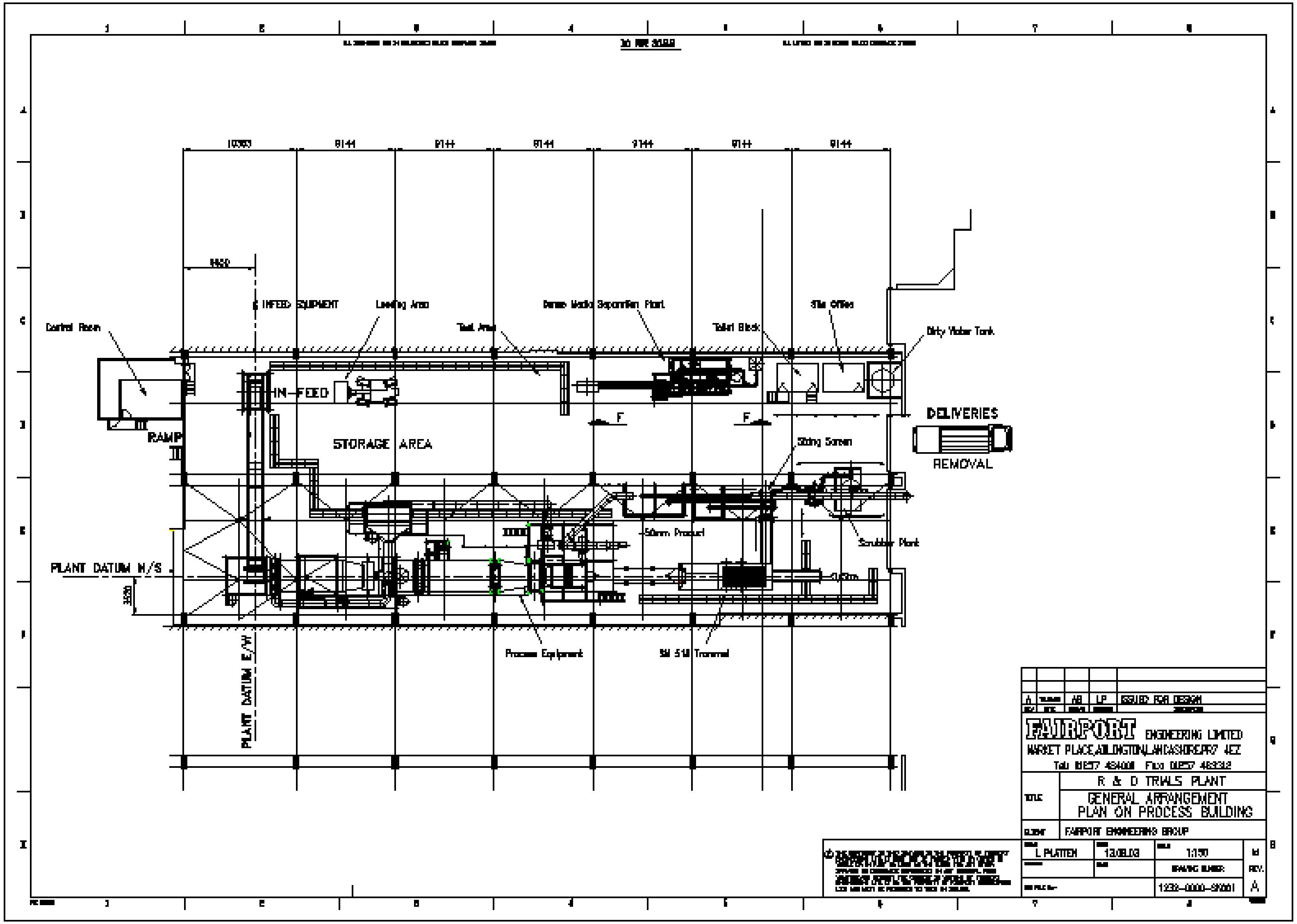
Enclosed at the end of the section and attached in Appendix B and C respectively are a drawing of the layout of the facility and a series of photographs highlighting key areas of the facility.

The major new development from the original process was the introduction of the Fairport Biomass Density Separator which has the potential to radically improve the quality of the Biomass products to levels not seen previously in this industry. This development is covered in more detail later in the Report.

The commissioning of the facility took longer than anticipated, partly due to re-designs, which benefited the Project, and partly due to the very nature of the feedstock. Dry commissioning was carried out using ‘ballast’ which was a mix of dry cans, bottles and plastics with no organic material. This ballast was used to individually calibrate and balance each piece of equipment followed by the system as a whole. A few surprises were encountered with ‘wet’ commissioning using ‘raw’ waste mainly due to the ‘sticky’ consistency of the material but these were quickly overcome.

The facility was ready to operate with waste shortly before Christmas having commenced design on Project approval in August 2003.

Plant Plan


10363
9144
Control Room
INFEED EQUIPMENT
Loading Area
Test Area
Dense Media Separation Plant
Toilet Block
Site Offices
Dirty Water Tank
IN-FEED
STORAGE AREA
RAMP
DELIVERIES
REMOVAL
Sizing Screen
50mm Product
Scrubber Plant
PLANT DATUM N/S
PLANT DATUM E/W
Process Equipment
SM 518 Trommel
ISSUED FOR DESIGN
FAIRPORT ENGINEERING LIMITED
MARKET PLACE,ADLINGTON,LANCASHIRE,PR7 4EZ
R & D TRIALS PLANT
GENERAL ARRANGEMENT
PLAN ON PROCESS BUILDING
FAIRPORT ENGINEERING GROUP
L PLATTEN
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1233-0000-SK001

3.2 Production of Large Batches of a Range of New Biomass Fuel Products for Sampling and Testing

In order to prove the suitability of the new Biomass products for use in the designated end markets it was necessary to produce sufficiently large samples to enable appropriate trials at power generation, cement industry and other industrial users' test facilities.

As has been indicated earlier a decision was taken to receive and pre-process waste at another facility. On receipt and under Fairport supervision the waste was physically 'mixed' and sorted using a mobile shovel and any undesired material was removed and disposed of at this stage. All the remaining material was then sized through a trommel screen. Initially this was sized to 200mm but this was quickly changed to a 150mm screen, which significantly improved the operational characteristics of the product.

The base operational plan was to test three different input materials. These were to be:

- -150mm material only,
- then -150mm material plus the oversize shredded down to 150mm and mixed,
- then all material shredded to 150mm.

The objective was to test and collate data on which of the input materials gave the best output product quality and best operational performance. After a number of weeks of tests it was decided not to shred all the material and instead to choose the mix of -150mm and shredded oversize as the preferred input product.

Over the thirteen week period of the operations from January to Easter a total of close to 900 tonnes of pre processed household waste were processed at Adlington all as detailed in Appendix D.

A significant exercise undertaken during the Project was the monitoring of the operational costs over the period. This proved to be surprising as usage costs were lower than originally anticipated. Details of these usage costs are attached in Appendix E. It was learned that in order to keep the facility clean and tidy additional labour over that planned was required.

The facility was operated under a full waste management licence, the first to be awarded to an experimental process on an existing industrial site. With the help of the Environment Agency a full Working Plan and Environmental Assessment was prepared and formed the basis of the operational procedures. A copy of the Working Plan is attached in Appendix F

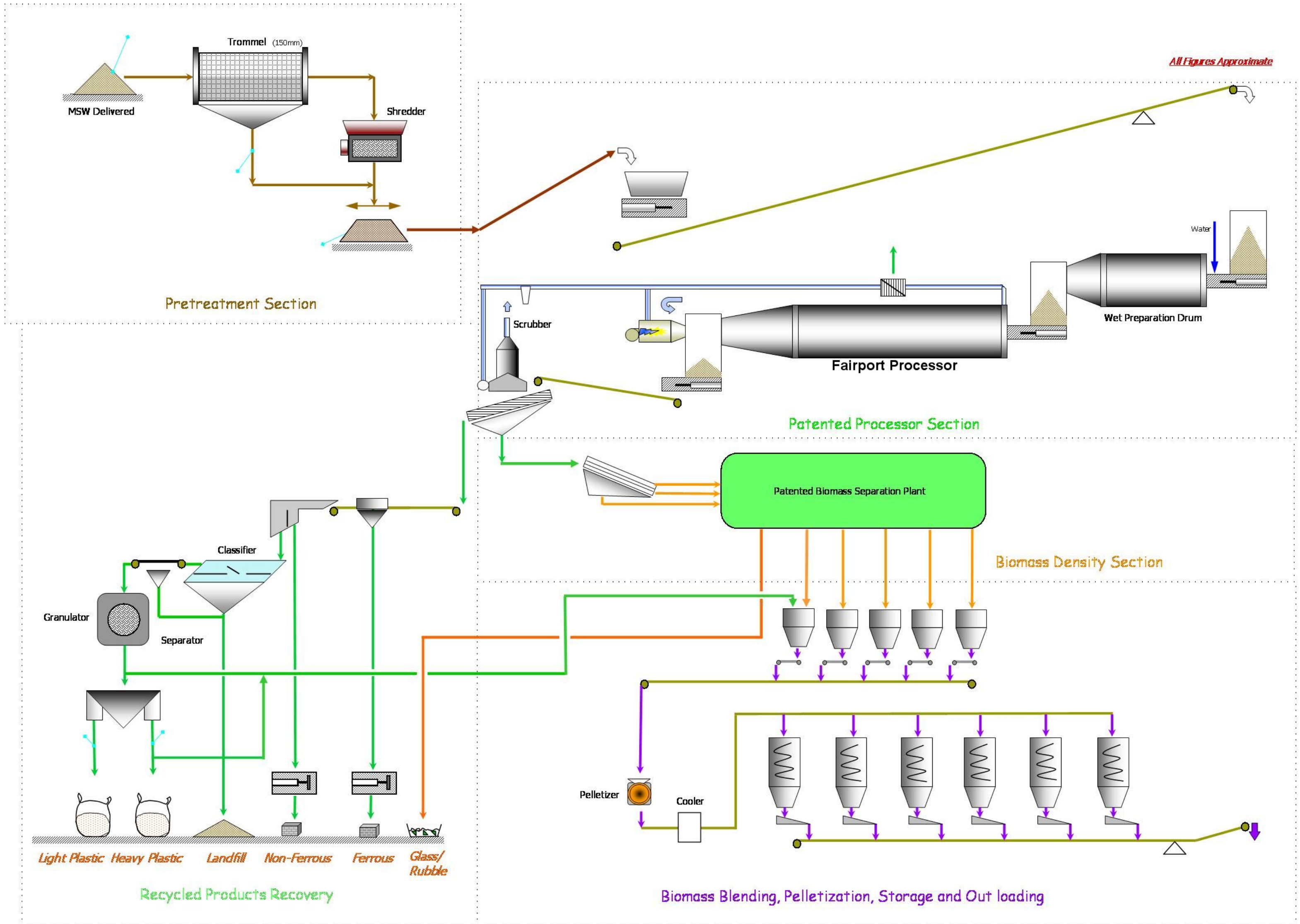
In addition the facility was operated in accordance with Fairport documented QA procedures and subject to Fairport Health & Safety regulations.

The following diagram includes a simplified mass balance flowsheet to indicate the process stream and equipment referred to in these sections of the report.

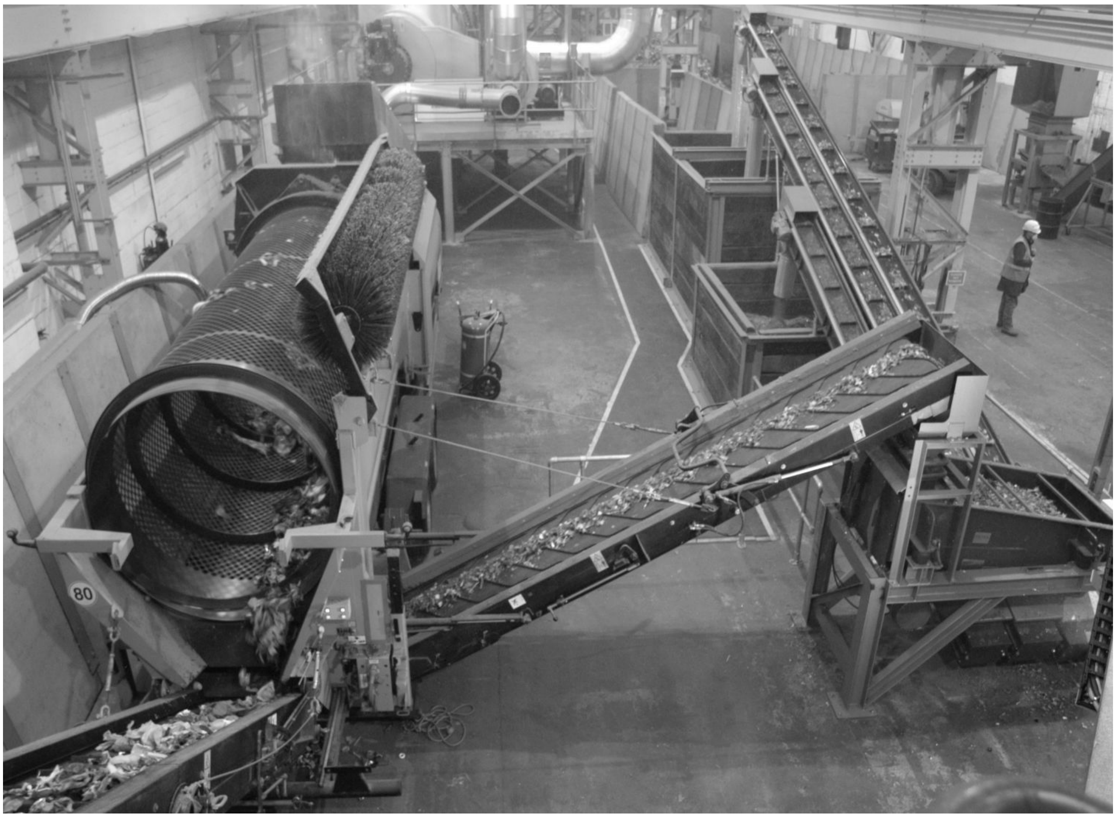
The main process material streams, or fractions referred to are:

- Received MSW loaded into the initial sizing trommel to size the MSW into two fractions: +150mm and –150mm
- Sized MSW at +150mm in size into the shredder
- Sized MSW from the trommel and shredder re-mixed together to form a consistent blended infeed material to the process.
- Wet preparation in the wet preparation drum
- Processing in the Fairport Processor
- Processed products outfeed from the processor to the initial sizing trommel
- Oversize (+50mm) processed products from the initial sizing trommel to stock for further separation
- Undersize (-50mm)processed products from the initial sizing trommel to the Rotex screen
- 3 sized fractions of processed products from the screen to stock, and then to the biomass density separator for further classification
- Refined biomass products from the density separator.
- Production of biomass fuel pellets in the pelletiser

Simplified Mass Balance Flowsheet



Wet Preparation Drum

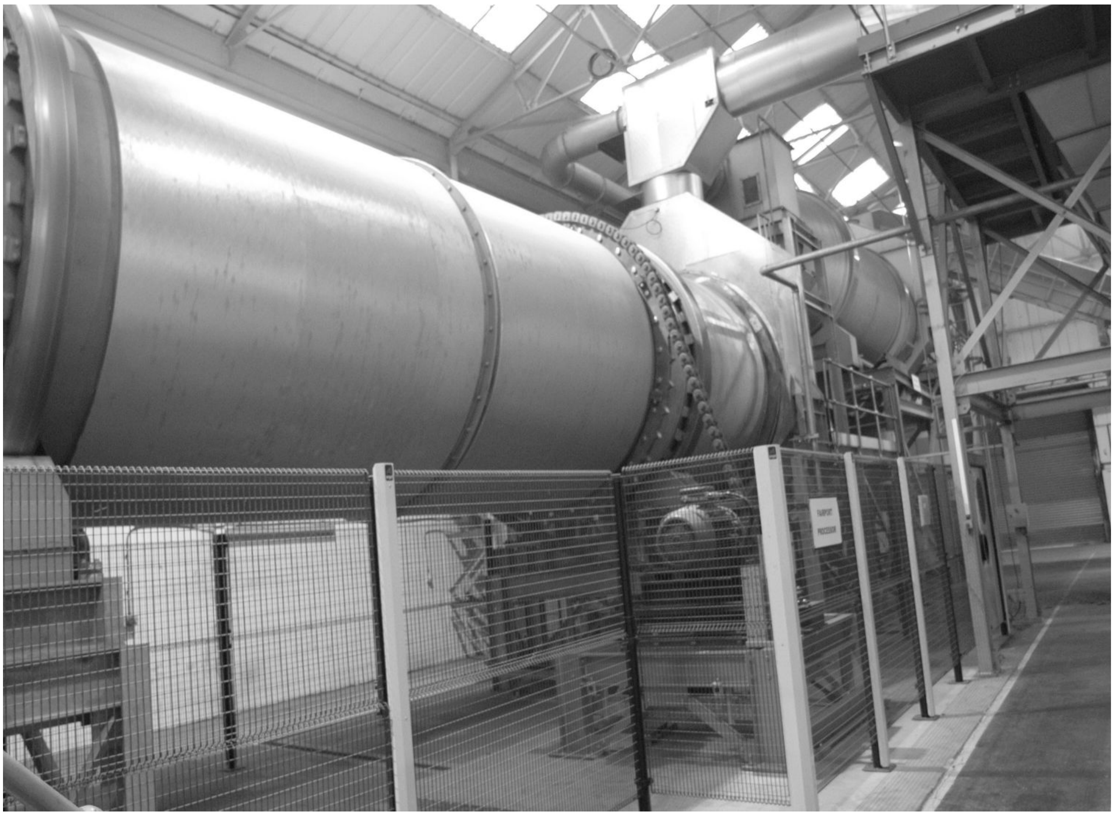


Primary Separation Trommel, Rotex Screen and Conveyors

Unrefined Product Stock Pens

Incoming Waste

Fairport Processor



3.3 Analysis of Process Inputs and Outputs

3.3.1 Process Inputs

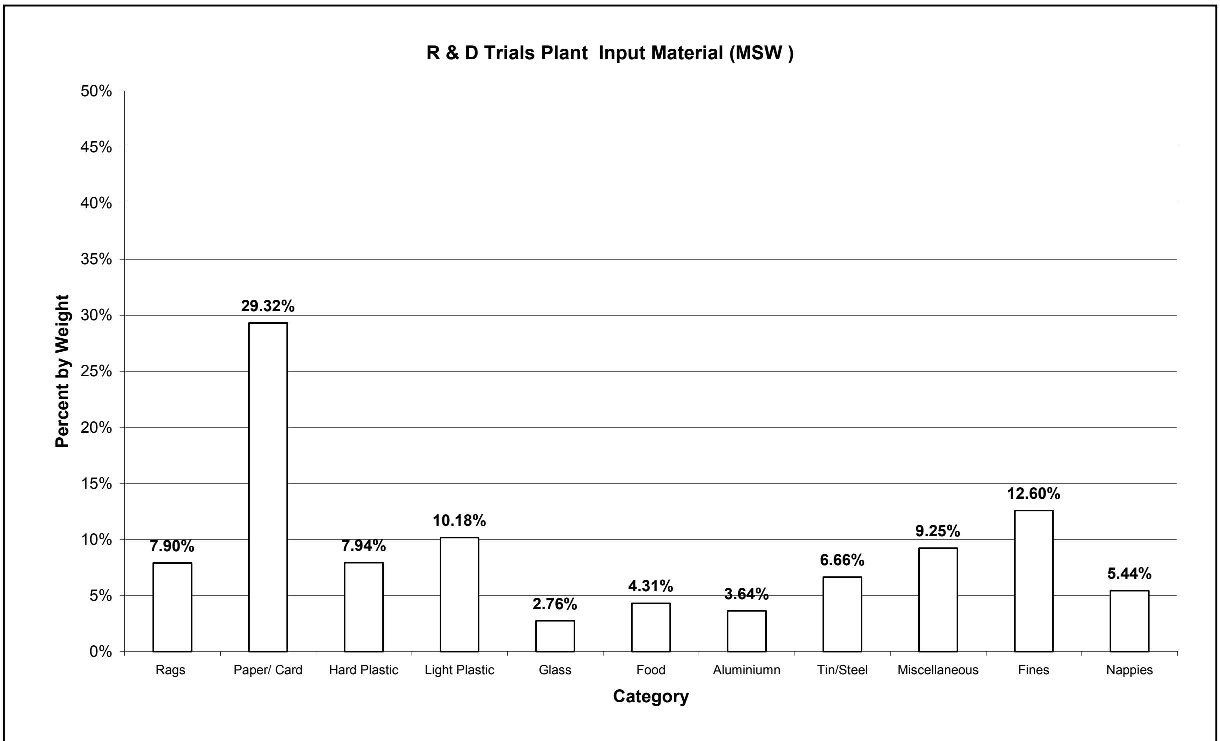
The variability of the process input Municipal Solid Waste (MSW) can cause problems for some processes. The design of the Trials Plant has overcome these issues to enable all forms of household waste to be processed.

As previously reported, the operational plan was to test 3 different input materials. Also after a number of tests it was decided not to shred all of the incoming MSW, and instead to choose the mix of –150mm trommeled MSW plus the shredded oversize.

Chorley Borough Council supplied the MSW for the trials programme from the local area during trials period. It is understood that Chorley Borough Council operates a doorstep collection of paper, glass, cans and garden waste.

During the trials programme the incoming waste was analysed by taking grab samples, and splitting them into constituent parts expressing each as percentages of the sample. These figures are expressed as a percentage wet weight of the incoming feed material and indicate a typical waste feed as processed during this time period.

The following chart details the average percentages of the various components as recorded from the samples taken during the trials. (In addition to the solid components MSW has variable moisture content of approximately 15 to 20%)



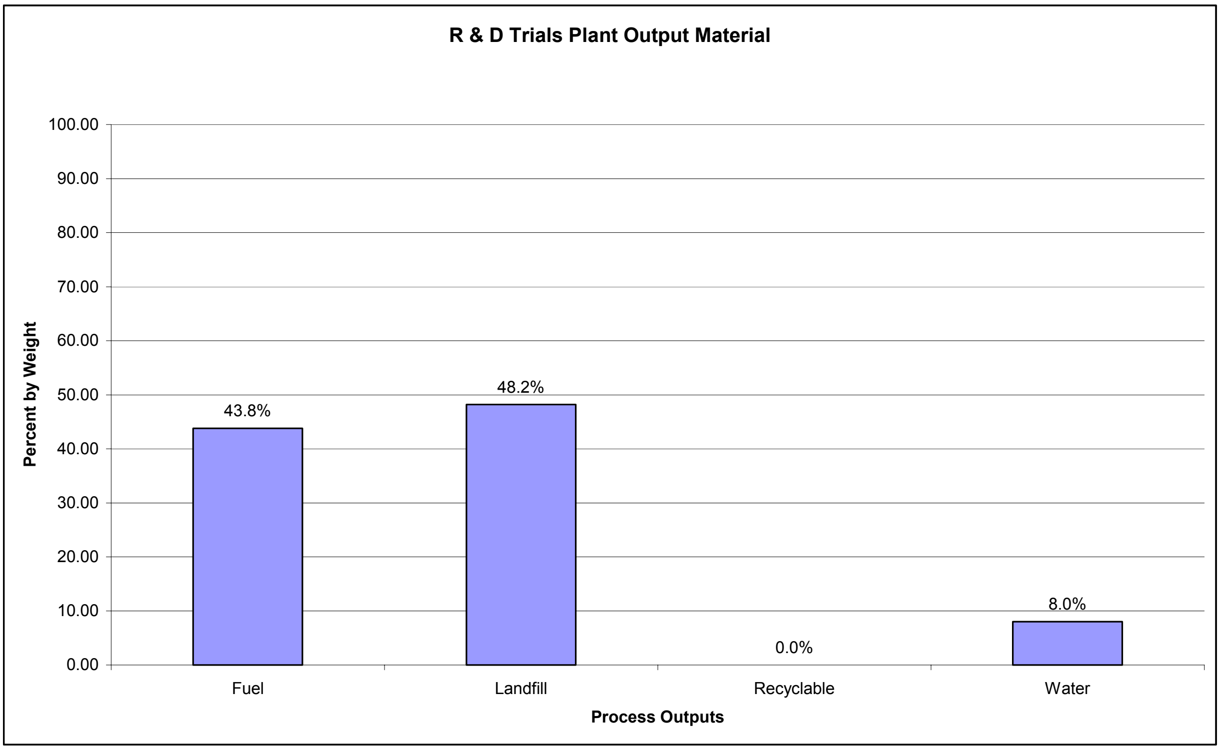
The processed Fairport output product steam was analysed and found to comprise of the following four categories:

Fuel Products
Recyclates
Landfill
Water content

- These figures are based on the waste material supplied to the process and the efficiency of the trials plant equipment and are therefore typical figures from that trial programme of the levels of each material presented to the three categories.

- It should also be noted that the weight of the output material is reduced from that of the input material due to the as received moisture content being reduced during the processing of the waste material into the final products.

- The following chart indicates the amounts of materials in the 4 basic categories: fuel products, recyclates, landfill and water (indicated s a percentage by weight)



Analysis and testing of the various Biomass Products was carried out. Details of these tests, analysis and assessments are contained in section 4.0 of this report.

3.4 Environmental Impact Assessment

3.4.1 Environmental Impact Assessment Report

The operation of the R & D Trials Plant presented the opportunity to monitor a large range of emissions. It is expected that the monitoring carried out will be sufficient to satisfy preliminary IPPC requirements.

The results of the monitoring and assessment activities have been analysed and reported on in the Environmental Impact Assessment (EIA) report (A full copy of this report together with its appendices is attached in appendix G)

The salient points from the EIA report regarding emissions from the plant are included in section 5.0 of this report.

3.4.2 Product Testing

A number of tests and assessments on the Biomass Fuel Products have been carried out including:

- Co-firing for suitability of RBF as an alternative fuel for power generation
- Gasification, to assess the suitability of RBF to produce a gas for use in a gas fired internal combustion engine
- Cement Kiln, assessment for suitability of RBF as an alternative fuel for firing in cement production kilns
- Laboratory testing, physical and chemical analysis

The results of the above tests and assessments are reported on separately in section 5.0 of this report.

3.4.3 Prevention of Pollution - Water Discharges

It was envisaged that large amounts of wash down water would be required for plant cleaning. To assist water retention and prevention of pollution a water sump was constructed under the wet preparation drum. The sump was fitted with a pumped discharge into a wastewater storage tank. Condensate drains from the air ducting and wastewater outlet from the emissions scrubbing unit were also piped into the wastewater tank.

It transpired that plant cleaning did not require this amount of wash down water and the waste water tank only required to be emptied once during the trials programme; with the majority of the water coming from the air ducting condensate and the waste water from the emissions scrubbing unit.

3.4.4 Health and Safety Audit

Health a safety audits were carried out on the plant and the operation together with regular visits from the Health & Safety Executive (H & S E). The H & S E recommended that for future plant designs additional trip wire / emergency stops and additional covers to prevent spillage of waste should be fitted to the infeed conveyor. These recommendations will be incorporated in future plant designs.

From the noise monitoring, although not mandatory, ear protection was issued to all staff in the plant with the instructions that it was to be worn.

A COSHH assessment was carried out on the work place air due to the visible presence of some dust in the air. Although the assessment revealed no significant issue to the operators, respiratory protection was issued to all staff with the instruction that it was to be worn in process plant areas. A copy of the COSHH assessment report is attached in appendix H

3.4.5 Product Storage and Handling

Large amounts of the RBF were produced during the trials and this was processed in the Fairport Density Separator into a range of quality biomass products.
Quantities of the refined biomass fuel products were than pelletised.

The key findings of the production of the pellets are as follows:

- Various different grades and sizes of the biomass fuel products produced satisfactory pellets
- The pellets produced were quite firm, retained their form and produced little or no dust whilst being handled
- There is little trace of any odour from the stored pellets
- The pelletisation process increased the bulk density of the biomass fuel form around 100kg/m^3 to 600 kg/m^3 therefore increasing handling and transportation characteristics
- The pellets have been stored satisfactorily over long term (6 weeks plus)

3.5 Separation of Outputs from the Process

3.5.1 Initial Sizing

Analysis of the processed Fairport products showed that the majority of the biomass fuels product items is less than 50mm. It was decided to carry out the initial sizing using a rotary trommel with a 50mm mesh. The oversize (+50mm) product contained larger items such as plastic bottles, trays, film, tin cans (clean and de-labelled), aluminium cans (clean), wood, rags and large textiles, with a small amount of miscellaneous items.

3.5.2 Oversize Product Material (+50mm from the initial sizing trommel))

Conventional equipment exists that can be used to separate these products with relative ease. This would incorporate the use of magnetic and eddy current separators and the removal of textiles, and provide ferrous metals, non-ferrous metals, textiles and plastics for re-cycling.

During the trials program the separation of these products was not carried out and the +50mm products materials were disposed of to landfill.

3.5.3 Undersize Product Material (-50mm from the initial sizing trommel)

The undersize product materials from the rotary trommel were fed into a Rotex screen and sized into 3 broad size ranges:

- -5mm
- +5mm to –16mm
- +16mm to – 50mm

These size fractions were put into stock prior to processing in the biomass density separator.
This separation into three unrefined products enables process of density separation to operate more efficiently. The unrefined products are fibrous, containing paper, plastics, putrescible materials, glass, ceramics and some small metal items. They have different characteristics and are handled separately in the Biomass Density Separator to produce a quality range of products.

3.5.4 Density Separation

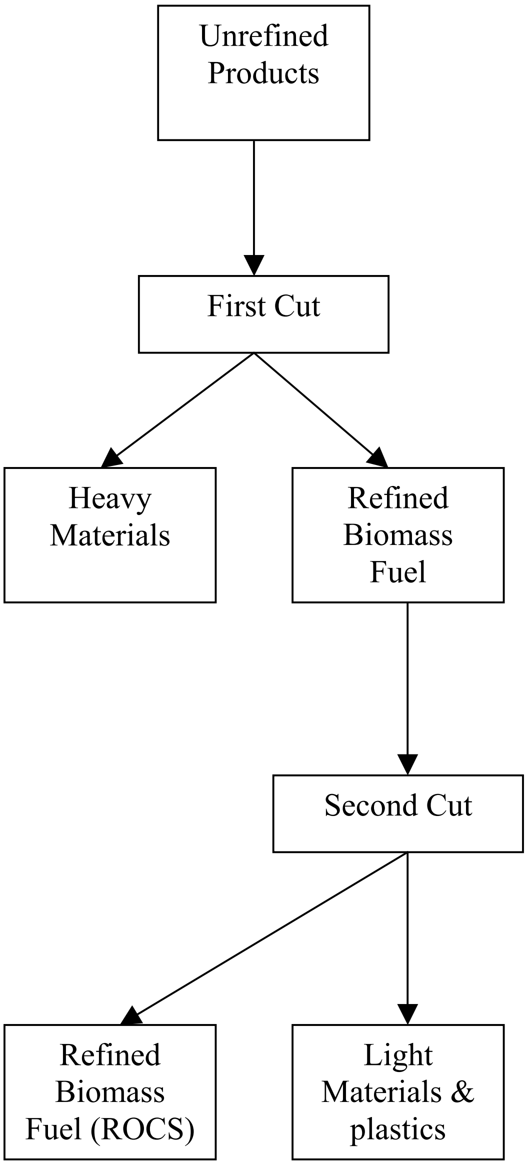
The objectives of the Biomass Density Separation plant were to remove the heavier non-combustible items from the lighter combustible materials and to enable more sophisticated removal of plastics to produce a range of quality Fairport biomass products.

Further details are included in Section 6 of this Report.

To produce the range of Fairport biomass products the density separation process followed the diagrammatic procedure shown below for each of the three size fractions referred to earlier.

Density Separation Procedure

Each of the three unrefined product size fractions are processed in the density separation unit as the schematic flow diagram opposite



A “first cut” was made of each unrefined product, resulting in the heavier materials being separated from the lighter ones. This presented the following products from each size range:

- Heavy items, glass, ceramics, stones, metals
- Biomass Fuel Product

A second cut” was made on the Biomass Fuel product to refine it further, removing plastics to produce a Biomass Fuel Product for the assessment of suitability for ROC’s (See section 4.6 of this report). This presented the following products:

- Biomass Fuel Products for ROC’s
- Plastic and light materials

The above separations were carried out on each unrefined products producing a total of twelve separate refined output products. The density separation plant has been designed to give a varying set of operating parameters and therefore the ability to manipulate the separation process to create a range of products that can be tailored to meet individual end user requirements.

The following table indicates the potential markets for the core products from the density separation of the Biomass Material from the initial – 50mm (undersize) processed feed stock.

Product Description	
RRBF Product for Co-Firing (ROC)	Co-firing in power stations
RRBF Product for Gasification	Production of gas for gas engine etc.
RRBF Product for Cement Industry	Firing cement production kilns
Mixed Plastic	Recycling Construction of House Building Products
Plastic Fuels	Pyrolysis – production of oils Microwaving – production of oils
Fines – for Light Weight Aggregate	Production of light weight aggregates
Road Aggregate	Mixed glass and heavies for use in road making

3.5.5 Biomass Fuel Pellets

After the Fairport fuel products were refined using the Fairport Biomass Density Separator trials were carried out on pelletising the various refined fuel products. This was achieved very satisfactorily, the following key observations refer:

- The biomass products pelletised, forming a hard compressed pellet
- Pelletising the loose biomass fuel reduced odour and dust emissions
- Increased storage life of the products
- No additional binding agents were required in the process
- The bulk density of the fuel product was increased from 100 kg/m^3 to 600 kg/m^3

3.6 Classification for Renewable Obligations Certificates (ROC's)

3.6.1 Rationale for classification of biomass fuels

If a fuel is to be used that is **not** one of the existing standard Carbon Fuels, the end user needs to be satisfied that he is receiving and combusting a material which has a constant calorific value (CV) as well as being approved by the relevant statutory bodies which control emission limits as well as usage.

3.6.2 Current Policy in the UK

At the present time in the UK, there appears to be a disparity between the Government policies on Waste Management and Energy.

This situation has come about through the fact that:

> Waste Management policy is the responsibility of DEFRA, and
>
> Energy (which includes fuels) is the responsibility of the DTi.

As part of the Project research the potential end users and the size of the markets for the new Fairport refined renewable biomass fuel products (RRBF) was surveyed and confirmed. It is apparent from this work that a major hurdle to be overcome is that of the definition of these biomass fuel products produced from processed waste into a Renewable Fuel resource. It is important to find a way of classifying this large volume of useful product since 45 to 50% of the process output from treating MSW (which has a biogenic origin) can be converted into new biomass fuel products

This biogenic origin material contains approximately 60% of the carbon energy value contained in MSW. Its origins are from paper, cardboard and other waste streams such as kitchen or garden wastes.

These biogenic materials need to be defined so that they can be classified in the same way as other biomass materials such as short rotational coppicing

3.6.3 Fuel Classification

The Project identified the need for these new Renewable Fuel Resources (converted from the biogenic material in the waste) to be defined legally as well as scientifically proven, to be of a specified standard and description which can be agreed by the two Government departments so that the processed Biodegradable Municipal Waste (BMW) can be utilised as a valuable renewable energy resource.

The proposed requirements to meet this definition or classification are as follows:

1) To ensure that the BMW, once processed, is no longer classified as a waste as long as it complies with laid down, legally defined process requirements i.e. its structure and chemical make up have been changed so as to produce a fuel of a consistent quality standard which is not detrimental to the environment or the health of the nation.

2) That there is an agreed scientific method for testing and defining the biogenic portion of the BMW so that it can be confirmed as a Refined Renewable Biomass Fuel (RRBF).

3) That this material is user friendly so that it can be used as a renewable fuel in types and classes of different energy production plants with efficiency levels exceeding 30% so encouraging and accelerating the creation of a low carbon economy.

If the above criteria are met, it would then encourage the use of these fuel products in power stations as long as it is classified as suitable for the Renewable Obligation Certification (R.O.C.s).

To meet this ROC's requirement it is important that the economic arguments in favour of the status quo are borne in mind but are not allowed to unduly influence the inclusion of new biomass fuel products in the criteria for ROC's accreditation. There is concern in the financial sector that the inclusion of new fuel products could 'dilute' the ROC's market and lead to reductions in the monetary value of a ROC.

3.6.4 Definition of a Renewables Obligation Certificate (ROC)

A Renewables Obligation Certificate is an obligatory requirement by the electrical supply companies to ensure up to 10.4% of the electricity that they supply is generated from renewable energy sources. This obligation was imposed on the electrical supply industry in 2002 with the value of a ROC being set at £30.00 per megawatt with a value increase of R.P.I. each year.

A ROC is thus a financial penalty imposed on the power supply companies if they do not meet the 10.4% target

This means that if the power Supply Company does not meet this target, it may have to pay the value of the shortfall into a recycling fund. The value of the ROC is calculated according to how many units of renewable electricity other suppliers have generated divided into the amount of money in the recycling fund. At the time of writing, this report (July 2004) a typical ROC is worth about £40.00 but it is understood that this could and will be reduced as the electrical supply companies supply more green electricity.

At the present time, a fuel that qualifies for a ROC has to have a purity level of 98% by calorific value.

If a new renewable fuel resource is to be used for co-firing with coal in power stations, the only way the power station owners would agree to use this fuel product would be if it was classified as meeting the ROC regulations and being eligible for ROC's. In addition it is important that this product from processed biogenic material should be classified as a refined processed fuel product in order that it no longer comes under the provisions of the waste incineration directive (WID).

It is not in the power station's interest to have to comply with WID as this would mean having to modify the power plant at great costs. It is also ironic that by using this fuel for co-firing, it actually decreases the emissions from the power stations since less amounts of coal are used but with little or no loss of overall plant efficiency. This would offset some of the initial investment costs of installing suitable equipment to enable them to handle and co-fire this type of fuel.

This would then entail formulating some form of sliding scale payment scheme based on the calorific value and purity of the biogenic fraction.

The research carried out to date on the project using the biomass density separator indicates that a purity level of 95 to 98% is achievable. However at this purity level only approximately 14% of the biogenic fraction can meet this purity level.

To fully benefit both environmentally and financially from this renewable energy resource it is essential that the issues of waste to fuel classification and purity of a ROC eligible product are clarified. It is important that these barriers are removed since the potential of this renewable fuel source is huge.

3.6.5 Fuel Market Tonnages

The potential market for the fuel products produced from MSW can become sustainable renewable resource if managed correctly so reducing the UK dependency on imported fuels. RDF = 5.50 million tonnes / annum (no ROC's*) RRBF = 0.88 million tonnes / annum (ROC's) Fines = 2.00 million tonnes / annum (no ROC's*)	
Now RDF can be used in the following (Potential)	
Cement Kilns	up to 1.2 million tonnes / annum
Gasifiers	up to 2.0 million tonnes / annum
Pyrolysis	up to 2.0 million tonnes / annum
Possible small plant (papermills)	0.3 million tonnes / annum
Fuel market value of -£5 to £0 / tonne to end user i.e they will not pay for it.	
Now RRBF can be used in the following	
Coal fired Power Stations * (@ 10% of Station Fuel)	up to 3 million tonnes / annum
Gasifiers	up to 1 million tonnes / annum
Now cellulosic fines can be used in the following	
Lightweight Aggregate Plants	up to 0.2 million tonnes / annum
Block Making Plants	up to 0.2 million tonnes / annum

Note * Not suitable for UK Power Stations if contains more than 4.9% plastic due to problems with milling

3.6.6 Legal Hurdles

At the time of writing this report there are separate attitudes on the legal stance:

1. The European approach is championed by Germany, Italy and Finland. This group, which includes technology providers, has been and is being, encouraged to develop European wide standards for Solid Recovered Fuels (SRF) processed from MSW. This group is also mandated by the European Commission to the development of European Standards on Solid Recovered Fuels and has been active since 2002 under the commission guidance group CEN/TC 343.

The UK government currently has no direct technical, political or commercial involvement and it is considered that this must take place if the UK is to have a say in this area which affects both the national waste and energy strategies.

2. The current UK stance is to abide by the existing European Laws on waste definition and not to be proactive in the formulation of the future generation of proposed fuel standards until it goes before the full European Parliament for discussion and ratification.

It is considered that this stance could be ‘too little too late’ and past history has shown that once a CEN standards group has been formulated and approved then little or no change to the recommendations normally occurs.

Therefore it is believed that in view of the research carried out and supported by DTi on the Project that a representative from the technical and environmental community be involved immediately in the CEN group to represent and influence this group on behalf of the UK Government and the emerging biogenic biomass fuel industry.

Attached in appendix S is the Renewable Obligation Certification Flowsheet

3.7 Energy Balance Evaluation and Benefits Comparisons

3.7.1 Energy Balance

The primary aim of the energy balance trials is to prove that (by measurement and monitoring during the R & D process) the process can deliver a renewable energy resource at an acceptable cost with minimal environmental impact.

The power utilised by the Fairport processor and associated equipment together with the throughput of waste was monitored and recorded directly. The trials plant used mobile plant for the pre treatment section and final conveyors. For these items the power use was estimated form the full rating of the equipment by an efficiency factor and rated throughput.

From the information collected a mass balance for the system was produced and an energy balance table generated.

The key findings from this trial are that:

The energy used was approximately one third less than predicted to produce the fuel products
The water used in the wet preparation stage was approximately 75% less than predicted from the initial pilot trials

The energy cost per tonne of processed MSW through the trials plant was calculated at:

Power£4.1

Gas (LPG) £5.31

Water £0.09

Total £9.50 / tonne

To facilitate the temporary location of the plant, and insufficient gas supply to the site, LPG was used for the Trials Program. It is expected that future plants would be fired by natural gas, natural gas being just over one half of the cost of LPG.
In addition future plants would be fitted with different emissions gas scrubbing units that would use additional energy.

Attached in appendix I are copies of the mass balance and energy balance sheets.

3.7.2 Comparison with Other Biomass Fuels

Information on various fuels has been collected, analysed and the following table drawn up. The table compares Biomass Fuel Products with re-claimed demolition wood and UK coal, presenting chemical and physical data where available.

In this table UK RRBF refers to the Fairport Renewable Biomass Fuel Product.

Comparison of Fuel Types

PARAMETER	Demolition Wood	Germany - Trokenstabilat	Mixed MSW	UK – RRBF Fairport	Italy - SRF	Byker RDF	UK Coal
Net Calorific Value (MJ/kg)	17	16.5	13.3	13.64	17.56	18.7	27.2
Moisture Content (%)	Not specified	Not specified	24.7	15.7	11.85	7.3	8.4
Ash Content (%)	Not specified	Not specified	16	13.3	19.26	15.0	10.2
Chlorine Total (%)	0.118	0.44	0.6	0.26	0.75	0.9	0.04
Sulphur Total (%)	0.17	0.2	0.2	0.34	0.33	0.3	1.0
Carbon (%)	Not specified	Not specified	Not specified	36.49	Not specified	55.0	83.5
Hydrogen (%)	Not specified	Not specified	Not specified	4.34	Not specified	7.3	5.4
Nitrogen (%)	2.93	1.7	Not specified	0.36	Not specified	0.6	1.7
Oxygen (%)	Not specified	Not specified	Not specified	Not specified	Not specified	35.9	8.4
Fluorine Total (%)	Not specified	Not specified	0.01	74.3 *	Not specified	0.01	trace
Cadmium (mg/kg)	4.1	2.2	0.6	0.33	1.9	0.0008%	0.00001%
Mercury (mg/kg)	1.5	0.75	0.4	0.1	0.6	0.0002%	0.00007%
Thallium (mg/kg)	Not specified	Not specified	<0.8	Not specified	Not specified	Not specified	Not specified
Arsenic (mg/kg)	4	0.8	3.0	3.0	0.48	Not specified	Not specified
Cobalt (mg/kg)	Not specified	Not specified	3.7	Not specified	Not specified	Not specified	Not specified
Nickel (mg/kg)	15.8	25	21.5	10.8	35	Not specified	Not specified
Selenium (mg/kg)	Not specified	Not specified	<2	Not specified	Not specified	Not specified	Not specified
Tellurium (mg/kg)	Not specified	Not specified	<1	Not specified	Not specified	Not specified	Not specified
Antimony (mg/kg)	Not specified	Not specified	10.1	4.1	Not specified	Not specified	Not specified
Beryllium (mg/kg)	Not specified	Not specified	0.2	Not specified	Not specified	Not specified	Not specified
Lead (mg/kg)	762	230	121	133	94	0.02%	0.003
Chromium (mg/kg)	48	60	70	14.1	95	Not specified	Not specified
Copper (mg/kg)	1390	200	59.5	28.2	18	Not specified	Not specified
Manganese (mg/kg)	Not specified	Not specified	Not specified	Not specified	142	Not specified	Not specified
Zinc (mg/kg)	500	400	Not specified	106	Not specified	Not specified	Not specified
Vanadium (mg/kg)	Not specified	Not specified	Not specified	23.1	Not specified	Not specified	Not specified
PCB's (mg/kg)	Not specified	Not specified	Not specified	<5	Not specified	Not specified	Not specified

Sources: Demolition Wood (Scheurer 2000), Trockenstabilat © (Heering 2001), Mixed MSWRefuse Derived Fuel, current practice and perspectives (B4-3040/2000/306517/MAR/E3), UK RRBF, Fairport Engineering Ltd – 2004, SRF Italian Data for RDF from Eco Deco (Solid Recovered Fuels), Byker RDF & UK CoalWaste Treatment and Disposal – Paul T Williams. * Fluorin e – expressed in mg/kg.

3.8 Data Collection and Project Management

3.8.1 Project Management

The R & D Trials Plant and its operation was managed throughout all phases from design, construction, commissioning and operation of the process trials. The project manager reported to the review board on a weekly basis to review plans, progress and resolve any matters arising.

Financial reports for each stage of the project were completed and reports, supported by auditable proven expenditure records were submitted to F.E.S. and N.W.D.A.

3.8.2 Data Collection

The individual trials were monitored and results were recorded throughout the duration of the test. The majority of the data used to form conclusions was obtained from the final steady-state period of running as results proved representative over the longer periods of running.

Limitations of the waste operative licence restricted operation of the trials plant to within normal working hours thus tests were carried out on a daily basis lasting for a period of approximately 8 hours.

Monitoring and recording of results can be split into that which were carried out automatically by the control system, that observed by the operational staff /engineers and data from collected samples.

The purpose of collecting this data was:

- To record the settings of the trials carried out
- To monitor the effects of changes to the settings
- To develop optimum parameters of the plant and process to achieve the desired products
- To determine the energy usage
- To determine the characteristics of the incoming waste
- To determine mass flow rates and splits of products
- To determine the energy balance
- To determine the efficiency of the plant and process
- To monitor emissions, determine emission levels and monitor to E.A. trigger levels
- To determine and monitor noise levels inside and outside the plant
- To record the data to assist with future pant design

The following summarises the monitoring and recorded data.

Item	Area	Analysis	Method of recording	Note
General	General	Event log	Operator log of plant conditions, setpoint changes and general observations.	
Process Temperatures	Throughout plant	10 continuous temperature readings	Thermocouple measurement automatically logged by computer and recorded every second.	
Feedrate	Infeed	Tonnage processed	Continuous belt weigher. Weighbridge and timed load.	
Feed Composition	Infeed	Bulk density. Composition by weight of component parts	Hand picking and separation by type.	
Water use	Wet preparation	Water rate	Continuous and totaliser logged by computer	
Power use	Main plant	Kilowatt hours	Continuous and totaliser logged by computer	Mobile plant not recorded nor Biomass Density separation plant.
Air system	Fairport Processor	Air flows	Manual measurement by differential pressure/ pieto tube.	
50mm	Primary	Separation	Mass flow	

Trommel	separation	Bulk density Oversize Composition	measurement for split of product by Grab samples Hand picking and separation by type.	
Emissions	Stack and surrounding area	VOC concentration Particulates Combustion gases	Continuous analysis carried out independently by accredited third party.	
Unrefined products	Primary Separation	Bulk density Moisture Mass flow Calorific value	Grab samples taken Combined sample analysis by third party.	Sample sent for gasification trials.
Refined products	Secondary separation Biomass plant	Bulk density Mass flow Calorific value	Grab samples taken Combined sample analysis by third party.	Pellets sent for handlabilty tests and burns trials.
Noise	Plant and surrounding area	Noise levels	Meter Monitored and set locations over given period.	

As described above the early trials were carried out to set the optimum parameters of the plant to achieve the desired product. During this period process temperatures were altered together with drum speeds, water addition and air flow rates. The products were examined visually and by calorific analysis.

The design and operation engineers recorded the observations made during the design, construction and operation of the plant.

Plant data recorded was analysed to produce a series of results to describe the process. A total of 33 trials were analysed the data recorded in each trail was made up of that automatically logged by computer, sampled and observed by engineers and from chemical analysis of product produced.

The data recorded by the control system included temperature measurements, water, power, tonnage and gas use. The data was collated into a single set from which average values were reported upon.

Attached in appendix J are records of data collected during the trials programme. These include:

- One set of information recorded from trial on 10/03/04. The data set consists of:

  - Operator event log – a record logged by the plant operator recording and changes to the plant set points, time of material feed and any events affecting the process.

  - Daily plant report – a report on the trial summarising the setting of the temperatures, air circulation fans, duration of trial etc.

  - Processor temperatures monitor temperatures (graphic) – information logged automatically of the process temperature and at various locations about the plant.

  - Logged data – in two parts temperature, continuous gas and power, water, tonnage and gas as totalisers.

- Logged data recorded on temperature and gas continuos use.

- Logged data recorded on power, water, tonnage and gas use

3.9 Project Completion and Site Clearance

The Trials Project completed with the last trial being carried out on the 1st April 2004, followed by processing of various samples for testing a commercial evaluation.

Residual waste has been removed from the storage area and disposed of to landfill. Process plant items have been cleaned and residual waste removed from drums, hoppers, conveyors and chutes etc; and has been disposed of to landfill.
Hired in equipment has been returned to the hirers.

The retained samples of the Biomass Fuel Products have been placed in containers, and the site generally has been cleaned and tidied.

Major fixed plant items at the time of writing this report have been cleaned and de-commissioned, but not yet removed from the site.

When the remaining plant items are removed it will then be necessary to "make good" the area in which the plant was situated and to satisfy the E.A. license surrender conditions.

4.0 TESTING BIOMASS FUEL PRODUCTS

4.1.1 Objectives of Testing

A major objective of the R & D Project was to develop a range of quality Biomass Products and test these products for quality, consistency and suitability as alternative fuel products.

In addition, laboratory analysis was carried out to assist in defining the products and proving the consistency and efficiency of the plant and process.

Evaluation and testing of the Biomass Products was carried out for:

- Extensive physical and chemical laboratory analysis on a range of Biomass products.
- Suitability of co-milling and co-firing of RRBF as an alternative fuel in conventional coal fired power station boilers.
- Suitability of the production of a gas from the RRBF to burnt as a fuel or used as a fuel to power a gas engine from a gasification process
- Suitability of the use of RRBF as an alternative fuel in cement kilns for the production of cement

4.1.2 Background to Laboratory Testing

The physical and chemical analysis of the processed products provides benchmark data on the composition of the biomass fuel products, and development of process controls.

On the initial Fairport pilot plant laboratory tests were carried out on a wide variety of the processed products. The objective of these tests was to prove consistency of the process and ascertain physical and chemical product composition, particularly calorific value (CV), and ash and moisture contents. In addition certain impurities were analysed and recorded.

These tests were carried out on refined and unrefined samples; the refined samples having had the heavy and plastic fraction removed.

The moisture content affects the resultant CV, therefore maximum moisture content was targeted at no more than 15%. It is also used as a measure of the quality and effectiveness of the process.

For combustion purposes and the generation of heat, the higher the CV the greater the heat output. Therefore the target for CV was to be as high as possible, whilst recognising that there is a variable level of impurities acceptable in the product specifications of potential end user products.

The ash content of a fuel sample is also an issue, and it is desirable for this to be a low as practically possible, targeted as less than 20%.

Impurities such as chlorine and sulphur were also monitored, when burnt they produce impurities in both emissions and gas, limits are set for the many different applications.

4.1.3 DTI Project Test Regime

This testing was an essential part of the whole trials program giving one set of indicators to the efficiency and effectiveness of the Fairport process; and providing data on the processed products. Moisture and ash content together with calorific values were closely monitored during the trials.

Moisture

Monitoring the moisture content of the produced products enabled process control parameters to be altered and derived; early tests gave moisture contents of 30 to 40%. These moisture contents were reduced by changing the heat input, air flow and drum speed settings of the plant, and it was seen that products were produced consistently with a 10 to 15% moisture content.

Attached in appendix K is a summary of laboratory test reports showing the various values for each sample. It can be seen from the early trials that the moisture content was in excess of 30%, and later dates many samples tested had a moisture content of 10 to 15%

Higher moisture content affects the products by reducing the CV and adversely affecting the storage life of the processed products. Low moisture content adversely affects the production of pellets from the fuel products.

Ash

In order to use the Biomass products as a fuel, the ash content needs to be as low as practically possible. This is the amount of ash that is produced when a substance is burnt. Non-combustible items such as soil, glass, metals will increase the ash content of a fuel product. It is therefore essential to remove as much of the non-combustible items as possible. Testing was carried out to measure ash content and this was used to monitor the effectiveness of the separation processes.

The table attached in appendix K is a summary of laboratory test reports showing the various values for each sample. The ash content can be seen to vary between samples (product code) unrefined products can be seen to have an ash content of 30 to 40%, where refined products, in pellet form product L of around 15%.

Calorific Value (CV)

For a fuel product the CV is very important, and can be varied greatly by the inclusion of differing materials. The ideal situation would be to produce a fuel product with the highest possible CV.
The biomass fuel products comprise mainly of organic materials such as papers, wood, food and other putrescible materials, each having its own CV. The maximum CV from this sort of material would be 16 to 17MJ/kg. The inclusion of material such as plastic would increase the CV but also increase the level of impurities produced when the fuel is burnt; and the inclusion of glass would reduce the CV and increase the ash content.

For co-firing of the Biomass fuel with coal the plastic content needs to be less than 5% and for gasification no more than 10%.

The Fairport Biomass Density Separator (see section 6.0 of this report) was developed to refine the Fairport biomass base products by not only removing the heavy fraction (glass, stones, etc) but also by removing plastic from the Biomass Fuel.

From the various tests and laboratory analysis it can be seen that consistent products were produced, with a Biomass Fuel having a CV of around 13.5 MJ/kg and moisture content around the 10 to 15%. Biomass fuel samples of this nature were used in the co-firing and gasification trials.

The list of laboratory results attached in appendix K shows values for calorific values for each sample. Sample 2 unrefined product of 5 to 16mm in size has a net CV of 2.573MJ/kg, where sample 231 refined product in pellet form has a net CV of 13.6MJ/kg.

4.2.1 Laboratory Testing

It was anticipated that during the R & D Trials program that a large quantity of samples would require laboratory testing and analysis. Fairport Engineering commissioned TES Bretby of Burton-on-Trent, Staffordshire to carry out the required testing.

TES Bretby is one of the UK's largest independent testing laboratories, employing over 250 chemists, engineers and technicians, capable of providing a wide range of testing, analysis, monitoring and support services for environmental and safety professionals; TES Bretby also operate under UKAS accreditation.

Prior to the commencement of the trial program TES Bretby supplied sampling and analysis methodologies and guaranteed staff and facilities together with the required turn round time for as many samples as Fairport may care to produce during the trials.

Copies of the methodology statements are attached in Appendix L

4.2.2 Testing Carried Out

Laboratory testing was required on large range of biomass product samples to determine the physical and chemical composition. It was thought that the optimum sizes of the initial separation of the products should be

- -5mm
- +5mm to –16mm
- +16mm to –50mm

As previously stated this was expected to present the product in size ranges to enable the most effective separation to take place.

Un-refined samples were sent for testing to ascertain the composition prior to separation.
Refined samples from the first and second cut off the density separator were sent for testing to analyse the effectiveness of the separation process by the removal of "heavy materials" and "plastic"

Some 240 plus samples were sent for analysis during the trials program.

4.2.3 Physical Analysis

The following physical analysis was carried out, with particular consideration to moisture, ash content and calorific value. The moisture content was used as a control check on the process, the target being around 15% by weight.

Moisture %
Ash %
Volatile matter %
Sulphur %
Chlorine %
Gross Calorific Value KJ/kg
Energy Density GJ/m^3
Net Calorific Value KJ/kg
Carbon %
Hydrogen %
Nitrogen %
Ash Fusion Temperature ^{o}C

In addition samples were sent for further chemical and elemental oxide analysis. This covered the following:

Chemical Analysis	Elemental Oxide Analysis
Antimony	SiO_2
Arsenic	AL_2O_3
Cadmium	Fe_2O_3
Chromium	TiO_2
Copper	CaO
Flourine	MgO
Lead	Na_2O
Mercury	K_2O
Nickel	Mn_3O_4
Vanadium	P_2O_5
PCB's	SO_3
Zinc	

A copy of a laboratory report showing chemical and elemental oxide analysis is attached in appendix M

4.2.4 Results of laboratory testing

- From the samples submitted and the laboratory results a comprehensive set of data has been collated.
- Analysis of various samples has proven that RRBF can be produced with a CV of 13.5MJ/kg, moisture content of 10 to 15% and an ash content of 13.5%.
- The RRBF produced is suitable for submission for co-firing and co-milling trials.
- The results were used to monitor the efficiency of the plant and process
- The results have been used for commercial evaluation and for submission to ascertain suitability and classification for ROC's
- From the earlier trials the moisture content of the fuel products was seen to be too high, refinement of the process parameters enabled final moisture content of 10 to 15% to be achieved consistently
- Calorific value of the various products varied across the sample range. The unrefined products (including the heavy materials) were much lower than the refined products.
- The final stages of the classification program (referred to as 1st and 2nd cuts), remove heavy materials and plastics from the fuel products with a view to producing the highest purity of product. It was seen that plastics could be removed to 95% purity, the cost and feasibility of producing the product to this level is a future consideration.

- The majority trace elements and elemental oxides of the levels measured are in line with current guidelines. One or two values are seen to be marginally high and are the subject of further consideration.

Attached in appendix M is a copy of a TES Bretby report, appendix L TES Bretby Sampling Requirements and appendix K a table of physical analysis results.

4.3 CO-firing Renewable Biomass Fuel Products

4.3.1 UK Legislation

The UK Government has imposed Renewable Obligations on the UK the Power Generation Industry. The current target is that by 2010, 10.4 % of the electricity generated will be produced from a recognised renewable generating source.

The Renewable Obligations Certification (ROC's) procedure is governing this process. For a fuel product to meet the requirements of ROC's it has to be 98% by calorific value a renewable Biomass product.
Power suppliers will be penalised if they do not meet these obligations.

Currently many different alternative fuel products are being sought for co-firing in conventional steam boilers, with consideration on suitability, availability, safe operation and commercial value. These fuels include alternatives such as olive oil residue, palm kernels, shae nuts, forestry residue, straw, chicken manure, reclaimed wood/timber and short rotational coppice and miscanthus.

Europe and other parts of the world also have similar objectives. This is placing a demand on the available products. The price of olive oil residue has already increased and it is expected the demand for these products will outstrip the available supply.

It was planned in the UK that by this date there would have been planted enough short rotational coppice to support the UK's co-firing regime. To date the UK appears to be significantly behind this target. There is an apparent reluctance to by the farmers to take up the crop due to lack of guarantee and an end market. The cost of this alternative is also a concern to the power generators.

Fairport Engineering Limited has developed a process to manufacture a Renewable Biomass Fuel (RBF) Product from Municipal Solid Waste (MSW). This fuel is available in large volumes and is both environmentally friendly and commercially attractive in co-firing applications in utility boilers.

These legislative rulings, the power generators needs and a sustainable supply of RBF has presented both Fairport and the Power Generators with an opportunity to test Fairport's RBF product for suitability of co-firing as an alternative renewable fuel source to meet the 10.4% requirement and the requirements of ROC's.

4.3.2 Technical Assessment of RBF

Power Technology – Powergen PLC were commissioned to carry out a technical assessment on the RBF products to assess its suitability for the purpose.

The proposed testing included:

- Analysis (proximate, ultimate, ash and trace metals) of three samples
- Thermal stability, explosion severity and minimum ignition temperature testing of the coal/BFP
- Combustion Test Facility, including:
  - Fuel preparation, grinding and transport
  - Test rig preparation and post test cleaning
  - Analysis of blend coal
  - 1 day combustion testing, with full gas analysis and carbon in dust measurements under air staged conditions to simulate co-firing in a utility boiler
  - Ash deposition testing and analysis
  - Disposal of any excess fuel
- Technical review, including:
  - Consideration of the likely flow characteristics in the mil bunkers, feeder and coal chutes
  - Consideration of the safety implication of co-milling Biomass with coal on air swept milling plant
  - Estimate of the impact on boiler emissions when co-firing the Biomass fuel with coal
  - Estimate of the impact on boiler operations when co-firing the Biomass fuel with coal
  - A view of the potential for BFP to be considered a Biomass fuel, based on microscopic analysis

4.3.3 Sample for Testing

A 250kg sample of +5mm 50 –16mm refined loose refined RBF was sent to Power Technology for co-milling with coal.
This is the product that Fairport are considering for the ROC's classification.

The RBF was co-milled at a 10% to 90% ratio with Kusbaz – Russian coal in a 2500 kg total sample.

4.3.4 Results

The main findings of the study are:

- Following these trials the power generators would be willing to use RRBF if it is classified as a fuel; and classified suitable for ROC's
- It was seen that the plastic levels of the sample tested had reduced from earlier samples analysed, first indication less than 5%.
- BFP has a high combustibles content, and has relatively high levels of volatiles, oxygen, and moisture. It is also however relatively low calorific value (13.6GJ/t net) and density (0.58t/m^3) and at around 8GJ/m^3 net has about one third the energy density of coal.
- Of the different forms of BFP supplied, the pelletized material is the most suitable for use in utility power plant.
- The composition of BFP (like most other biofuels) is not well suited to processing in UK utility milling plant, however it is believed that the co-milling of small proportions of BFP pellets with coal (5-10% by mass) is possible.
- In a blend of 10% BFP with coal the thermal stability and explosion properties of the coal dominate and the adverse thermal stability characteristics of the pure biofuel are avoided.
- The milled fines from BFP exhibit very poor bulk handling properties whether present as pure BFP or a mix of BFP and pulverised coal. Indirect firing and the blending of milled BFP with raw coal are both strongly discouraged for application to existing boiler plant. The selection of milling plant for co-milling trial work needs to take into account the classifier rejects return system design to avoid potential blockage problems.
- During the combustion tests the flame length, shape, intensity, smoke generation, ignition point and stability were all found to be typical of the characteristics of a flame from the firing of pulverised coal alone. The most arduous case of 25% over fire air and minimal overall excess oxygen was tolerated without loss of stability.
- There were no significant adverse effects in respect of CO, unburned carbon, NOx, or the effectiveness of OFA as a means of NOx reduction when firing the BFP blend on the CTF. The NOx levels achieved for an equivalent level of unburned carbon were the same to within the confidence limits of the tests undertaken.
- Even at the low blend ratio used for the CTF tests the presence of BFP in the pulverised coal resulted in a significant increase in the sintering and fusion of ash deposits. This effect is likely to increase in proportion to the blend ratio and at 10% by mass raises the ash deposit strength of typical import coal to a level similar to that of UK coals.
- The potential fuel availability makes direct injection rather than limited capacity co-milling an attractive option although transportation to site may become a limiting factor for its utilisation. Transported fuel is likely to be pelletised however if

processed locally the requirement for pelletisation might be avoided depending on the plant design. Further consideration should be given to rail delivery.

- Dedicated fuel reception, storage and handling systems will be required for BFP with the lean phase pneumatic transfer of the pure pelletised material being the preferred handling option.
- Direct injection systems will require additional dedicated milling plant, fuel supply pipe work to the boilers and new furnace injectors/burners.
- When blended or co-fired with coal the use of BFP is likely to result in little change in SOx, NOx and particulate emissions whilst providing CO_2 reduction due to the displacement of an equivalent quantity of coal derived heat.
- The total trace metals content of BFP are high and even in a BFP/coal blend the ash will contain high levels of lead, zinc, and antimony. The trace metal concentrations found in BFP are outside the typical Biomass material IPC authorisations for co-firing on Powergen plant and it is likely that the Environment Agency will demand extensive work to determine the fate of these trace elements. This issue is likely to be a significant obstacle to the widespread use of BFP.
- The effect of adding BFP to typical world traded coals in terms of bulk ash composition is limited to increases in calcium and sodium oxide that might be expected to increase the probability of sintered ash deposits. The severity of this at the proportions of BFP to be used are however likely to be within the range seen when firing coals from different origins.
- The chlorine content of BFP is relatively high for a biofuel, although when blended with coal and particularly with lower chlorine imported fuels, this impact is significantly reduced. It is unlikely that high levels of chlorinated organics will be formed during combustion of BFP.

A number of recommendations have been made to enable the future continuation of the project to exploit BFP and these are detailed in the main body of the report attached in appendix N

4.4 Gasification Trials

4.4.1 Gasifier

With knowledge of other development projects in the UK Fairport Engineering were encouraged by the DTI to approach Biomass Engineering Limited and work together to explore possible opportunities in gasification of the Fairport Biomass Fuel Products.

Biomass Engineering Limited have developed a 250 kW down draught gasifier. This was originally designed to process waste from the leather industries. Biomass engineering has carried out some modifications to the plant to enable the process trials on the Fairport RBF to be carried out, and produce a gas of acceptable quality.

4.4.2 Testing Carried Out

The following samples were sent for to Biomass Engineering.

- 0 to 50mm refined first cut loose RRBF
- 0 to 50mm refined first cut loose RRBF with an additional 25% added plastic
- 0 to 16mm refined first cut loose RRBF

Four trials were carried out on the 0 to 16mm RRBF that was briquetted for handling and feeding purposes prior to the gasification trial.

It is understood that further tests are to be carried out.

4.4.3 Results

- The indications from Biomass Engineering Limited are that they were excited and encouraged by the results of the tests carried out on the RRBF material
- The RRBF was gasified for a period of 4.5 hours and a gas suitable for the purposes of running a gas internal combustion engine to generate electricity was produced.
- The gas produced was analysed, temperatures measured and analysis of the ashes carried out, the gas produced was of a good quality, had a flame temperature of 550 to 600 $^{\circ}$C and had a low tar content
- The RRBF made from the trials is satisfactory for making pellets and briquettes for the use in gasifiers.
- From this trial it was found that the amount of plastic and glass in the Biomass Fuel Product is critical to the gasification process, too much of either is an issue (10% plastic maximum, and as little glass a possible) at present.
- Due to operational difficulties at Biomass the trial with 25% added plastic could not be carried out

- Biomass Engineering identified some modifications to the gasifier that would enhance the performance and gasification of the briquetted RRBF.
- Biomass Engineering Ltd. feel that with further developments and the design of a gasifier tailored to the Fairport material the HHV of the gas can be improved significantly to a level comparable with that of leather wastes.

It would therefore be the aim of Biomass Engineering Ltd. to investigate:

- Gasifier bed geometry to optimise char bed formation and improve down flow of by-product char and ash. This would also involve grate re-design to include direct removal of char and ash from the bottom of the gasifier.
- Optimise fuel briquette density and increase the moisture content to improve gas quality and CV.
- Measure tar contents in the product gas to assess gasifier performance
- Use varying quality feedstock.

The Biomass Engineering report on the gasification trials is attached in appendix O

4.5 Cement Kiln – Alternative Fuel

4.5.1 Current Position

There are 13 sites in the UK using fired kilns for the production of cement. Some of these facilities are already using alternative fuels to the more traditional oil or gas firing. These fuels include alternatives such as tyre chips, pelletised sewage sludge, paper and plastics.

Producers of cement are currently looking for additional alternative fuels as an economically viable and sustainable source of supply.

Fairport Engineering Limited has developed a process to manufacture a Renewable Biomass Fuel (RBF) Product from Municipal Solid Waste (MSW). This fuel is available in large volumes and is both environmentally friendly and commercially attractive as an alternative fuel for firing cement kilns.

Fairport and the Cement Producers have identified an opportunity to test Fairport's RBF product for suitability of firing in cement kilns and have under gone some initial testing.

The requirements for firing in a cement kiln are somewhat different to the co-firing needs of a power station boiler. The fuel classification does not have to be so refined, in fact the inclusion of glass is seen to be of benefit, therefore less post process grading is required, and the coarser size products are also considered suitable.

4.5.2 Testing – Cement Kiln

Rugby Cement and Castle Cement are interested in burning the Fairport RBF in their kilns and are working together with Fairport to test the products for operational suitability

The assessment of the RBF comprised of burn trials and chemical analysis of samples of RBF fuel products.

Samples of the RBF have been sent to Rugby cement and chemical analysis of the product has been completed. The laboratory report is attached in appendix P

4.5.3 Sample for Testing

Two samples of approximately 10 kg of RBF were supplied to Rugby Cement for testing. These samples were:

1 - +5mm to –16mm unrefined loose product.
2 - +16mm to –50mm unrefined loose product.

4.5.4 Results

Information on the trials carried out is still awaited. The indication so far is that RBF is a suitable alternative fuel for firing in a cement kiln.

5.0 EMISSIONS AND ENVIRONMENTAL ISSUES

5.1 Environmental Impact Assessment

It is important to recognise that this project represents the first time in the UK that a waste processing plant has been built, operated and licensed on a manufacturing facility which is not a permanent waste processing site. As a DTI R&D Trials Facility it was important that all legislative matters were properly adhered to and Fairport adopted a position of using the opportunity to investigate and implement all requisite environmental control procedures.

After consultation with the Environment Agency (E.A.) in Preston a waste management licence was issued and in January 2004 Fairport Engineering Limited began what eventually resulted in 13 weeks of operation and trials.

During the trials programme Fairport liaised closely with the E.A. This comprised of discussions on the setting up of the license, advice given in developing the working plan for the plant, regular visits to site during processing, and submission of information to the E.A. on completion of the trials and production of reports.

As a result Fairport implemented the following:

- Monitoring of emissions from the stack
- Monitoring of Ambient air at site boundary
- Monitoring of air inside the workplace
- Monitoring of noise
- Site checks and inspections in accordance with the waste management license
- Control of waste, deliveries and despatch
- In addition to the stipulated monitoring in the waste management license the following was carried out:

    - Polychlorinated dibenzodioxins (PCDDs) & Polychlorinated dibenzofurans (PCDFs)
    - Oxides of Nitrogen (NOx) expressed as Nitrogen Dioxide (NO_2)
    - Oxides of Sulphur i.e. as sulphur dioxide (SO_2)
    - Oxides of Carbon i.e. Carbon Monoxide and Carbon Dioxide (CO & CO_2)
    - Hydrogen Fluoride and Hydrogen Chloride (HF & HCL)
    - Oxygen
    - Ammonia (NH_3)
    - Hydrogen Sulphide
    - Bioaerosols
    - Odour Threshold
    - Moisture

In addition to the above, section 3.4 of this report also refers to the Environmental Impact Assessment (EIA). A report on the EIA has been produced and together with its supporting information is attached in appendix G of this report. The following sections of this report contain salient information from the EIA on emissions and noise monitoring and on the control of waste.

5.2 Emissions Monitoring

5.2.1 Emissions Monitoring Consultants

It was a condition of the waste management licence that emission monitoring was carried out as part of the control of pollution activities. Fairport commissioned an independent specialist company Resource Environmental Consultants Limited (REC) to provide all the necessary monitoring equipment and staff to monitor and analyse the emissions.

5.2.2 Monitoring of Emissions from the Stack

The waste management licence stated a number of trigger points or total limits for certain substances in the emissions from the process.

The following table indicates the features that were set with a trigger level by the E.A., the initial trigger level and the revised trigger level where appropriate together with the level of each measured during the monitoring programme.

Features	E.A. Trigger Level	Revised E.A. Trigger Level	Levels Recorded
Total Dust	10mg/m^3	N/A	1.3 to 5.1mg/m^3
VOC's	10mg/m^3	100mg/m^3 ***	50 to 90mg/m^3
Hydrogen Chloride	10mg/m^3	N/A	0.1 to 0.5mg/m^3
Cadmium / Thallium	0.1mg/m^3	N/A	<0.01mg/m^3
Mercury	0.1mg/m^3	N/A	<0.01mg/m^3
Heavy Metals	1.0mg/m^3	N/A	0.04 to 0.77 mg/m^3

*** Once we had proven from laboratory analysis that the greater percentage of VOC's are none carcinogenic and of a natural formation.

With the exception of VOC's the monitoring showed results inside the E.A. limits.

The limit set by the E.A. for VOC's was 10mg/m^3, the flame ionising equipment fitted in the stack was capable of measuring total VOC's down to a limit of 1 mg/m^3.
Toward the end of February it was identified that VOC levels of between 50 to 300mg/m^3 were being recorded. This was a huge surprise and the findings were reported to the E.A. and tests were suspended whilst investigations were made into potential causes.

It was decided to take the following remedial action:

- Focussed testing and analysis by independent consultants and at Leeds University
- Sourcing of additional VOC removal equipment
- Modifications to the airflow within the existing plant

Following modifications to the air separator and removal of a blockage in the stack which was affecting the airflow, tests were carried out to assess the success of the changes. As a result of these modifications the levels of VOC's reduced significantly form the 300mg/m^3 down to a range of 50 to 90 mg/m^3. Although much reduced this level was still much higher than the set level of 10mg/m^3.

From investigation into other waste treatment processes and standards set for other processes it would appear that this limit of 10mg/m^3 was set too low. From real life testing data that a figure closer to 100 to 130 mg/m^3 should be set as a standard for this type of processing plant. It was felt that this target was unachievable without the fitting of a VOC afterburner, which was not considered to be an appropriate environmentally friendly option.

Far from being an arbitrary level it was noted that a process used by others on the same Adlington site was operating under a condition of 150mg/m^3. Because the level of VOC emissions was still higher than the E.A. trigger level of 10mg/m^3 two separate independent reports were commissioned from REC and Acqua Enviro. Copies of these reports are included in the as appendix 5 in the E A report in appendix G of this report.

The REC report focussed on some 8 weeks of intensive VOC monitoring and concluded that the VOC emission levels did not constitute a hazard to health.
The Acqua report focussed on analysis of the individual VOC's contained in a series of samples. Again the conclusion did not find any danger in the VOC emission levels. Simulation testing at Leeds University indicated that similar levels of VOC's could be expected.

The evidence collected in the above reports was shared at a meeting with the EA and the local Environmental Health Officer where it was agreed to recommence operations and closely monitor VOC levels
And the performance of the gas scrubbing equipment.

During the trials issues were experienced with the reliability of the gas scrubbing equipment and its operational reliability. The capacity of the unit was also found to be too low for the volume of emissions to be scrubbed. At the end of the trial programme the unit was seen to have failed with a dosing pump needing replacement. Future plant design will incorporate a different type of scrubbing unit capable of handling the complete emission flow.

5.2.3 Monitoring of Ambient air at Site Boundary

The objective of the ambient air monitoring was to assess the impact of the R & D Trials Plant on concentrations of various pollutants prior to and during the operation of the plant.

The survey included monitoring of a number of pollutants, which may be affected by emissions from the process; these were measured adjacent to the cottages at the rear of the yard and the main site entrance next to the gatehouse in particular:

- Sulphur Dioxide
- Nitrogen Dioxide
- Benzene, Toluene, Ethyl benzene & Xylene (BTEX) compounds
- Speciated VOC's
- Total suspended particulate matter
- Heavy Metals

The survey found that the measured ambient concentrations of the above pollutants were well within the stipulated air quality guideline values and standards, both prior to and during processing operations. This indicates that the process itself in not having any significant impact on the surroundings, above the general background levels.

5.2.4 Monitoring of Air inside the Workplace

Workplace monitoring was carried out on personnel involved in all aspects of the process and also at specific work areas, in particular:

- Loading waste into the infeed hopper
- Transfer conveyors
- Fuel product storage areas

The survey involved the measurement of the following hazardous substances in the workplace air at either static locations or on personnel working in the process area.

- Total inhalable and respirable dust
- Bioaerosols
- Respirable heavy metals
- Speciated volatile organic compounds VOC's
- Man made mineral fibres MMMF

The locations covered the monitoring positions agreed with the Environment Agency as a condition of the waste management license. All the dust, metal, VOC and MMMF levels measured are below the levels quoted in EH40/2003 in all areas tested.
There is no figure quoted for bioaerosols in EH40/2003. The levels recorded are within the range expected for a workplace as advised by the Health and Safety Laboratories.

5.2.5 Monitoring of Noise

As part of the R & D Trials Plant operation and testing, Fairport undertook a number of noise monitoring surveys to assist in developing standards for the operation of this type of facility. This included noise monitoring external to the plant, recording noise transmitted to the local environment; and noise monitoring inside the R & D Trials Plant where personnel where working. This report summarizes the results of the monitoring and details observations and conclusions based on the results obtained.

Key Findings

- The R & D Trails plant equipment ran very consistently. When operating each piece of equipment operated at a steady condition, producing a consistent noise level
- During external noise surveys it was difficult to identify noise being generated by the R & D Trials plant from other noises in a shared facility generated by other users, traffic, loading unloading and general machinery noise
- The general noise level monitored adjacent to the cottages in the rear yard when the plant was running was around 52/53dBA, which was around 4dBA higher than when the plant was not running. It is thought that the generator positioned external to the plant building would contribute to this difference.
- The general noise level monitored adjacent to the gas tanks in the rear yard when the plant was running was around 63/64dBA, there was very little difference when the plant was not running
- The general noise level at the gate house, front yard varied from 59/60dBA up to 67/68dBA. The lowest level recorded was 59/60dBA

when the plant was not running. It is not thought that the R & D Trials Plant operation added any noise to the values at this position.

- The general noise level monitored in the front car park varied from 55 to 59dBA. There was no apparent difference when the R & D Trials Plant was running or not running.
- Higher peak levels of noise were recorded from other sources / users of the shared Fairport Site Yard.
- The noise levels recorded inside the plant whilst the plant was running, at various points and specific pieces of equipment ranged from 60dBA to 106dBA. There were a number of recordings where the mean values was around the 85dBA level with the pellet mill and density separator being over the 90dBA level.
- The results of the surveys for each piece of equipment demonstrated that there was an average noise level of between 80dBA and 90dBA. From the initial noise assessment it was expected that noise at these levels would be generated whilst the R & D Trials Plant was in operation. The whole plant area was then designated as mandatory for the ear protection to be worn and all personnel were issued with ear protectors.
- Noise levels recorded at J Dickinson's plant were also at a level where ear protection should be worn, these results have been passed onto K Dickinson.

Data has been collected and is contained within the full environmental impact assessment report (Attached in appendix G) and will be used in consideration of future plant design (including for example noise reduction levels through the fitting of acoustic screens and covers) and setting of future standards for this type of plant.

5.2.6 Site Checks and Inspections

As a condition of the license a number of daily and weekly checks were carried out on the Trials Plant and the surrounding property, these included:

- Site security
- Litter
- Pestilence
- Scavengers
- Olfactory Monitoring
- Aerial Emissions
- Site Notice Board
- Engineered Containment Systems

With the exception of the previously stated VOC situation no issues were encountered in the above areas. The checks were carried out, noted in the site diary together with any remedial actions taken.

5.2.7 Control of Waste, Deliveries and Despatch

During the Trials Programme waste was delivered directly to J Dickinson and then to and removed from Fairport in steel skips. Each delivery or collection was weighed on a weighbridge and the details recorded, the relevant transfer notes being issued. No issues were experienced with litter or pollution to the site from these vehicle movements. The details of the deliveries and collections are contained in the waste control record sheets attached in appendix Q.

A key factor n the success of the operation was the relationship between Chorley Borough Council (Chorley), J Dickinson & Sons Limited (Dickinsons) and Fairport Engineering Limited (Fairport).

It was seen that all parties worked well together and a positive relationship ensued throughout the Trials Programme.
This greatly assisted the Trials, providing flexibility of: operation, delivery and collection times, holding and storing waste, use of the transfer station when the landfill tip was closed. These were all key learning points that helped facilitate successful process trials.

5.2.8 Additional Monitoring

For this R & D Trials Programme Fairport did not apply for IPPC authorisation.
The DTI together with the Environment Agency agreed that a dispensation should be given on the understanding that a project objective was to collect information and assist in future target setting.

However the opportunity was taken to carry out additional monitoring that may be expected to support future IPPC applications.
For future plant developments IPPC approval would be applied for. The data collected is contained in the REC Technical report attached in appendix R.

6.0 FAIRPORT BIOMASS DENSITY SEPARATOR

6.1 Background to the Biomass Density Separator

This DTI Project successfully proved that Fairport could produce products suitable for use in the end markets. However to increase the commercial potential of the products it was necessary to further improve the refinement and quality of these products. This was achieved through the development of the prototype Fairport Biomass Density Separator which uniquely has the ability to not only remove all 'contaminants' (glass, plastics, metals) from the 'base' products but also provide the opportunity to increase the range of products by leaving certain elements such as plastics in the product (to boost calorific value) or to blend the biomass products with other wastes.

Extensive testing was carried out during the development of the Fairport pilot plant and through the development of the full size DTI plant to refine the products produced. Conventional technology was used to separate items of such as metals, glass, plastics, textiles and early tests were aimed at finding effective ways of separating the combustible materials from the non-combustibles and then to improve the quality of the final products by removing further impurities.

The Fairport pilot plant trials were still producing products that had contaminants in them and research and testing was carried out to develop techniques to improve the quality.

A classification unit using air knifes was tried, followed by a fluid bed separation unit. Both of these pieces of equipment separated light materials from heavy materials very successfully, and therefore gave a good split of combustibles to non-combustibles. Further refinement of the removal of impurities was still required to make the fuel products more suitable.

Fairport used its conventional process engineering skills to develop refinement techniques and trials proved that these represented a major step forward in improving the quality of the products and the ability to vary them to suit end user markets leading to the design and build of the Biomass Density Separator (BDS).

6.2 Development of the Biomass Density Separator

The prototype Biomass Density Separator was designed and built as the final stage separation process of the DTI facility

The initial objectives of the Biomass Density Separator plant were to remove the heavier non-combustible items from the lighter combustible materials. As the test program developed a further process to allow more sophisticated removal of plastics from the lighter materials was also introduced.

The development of the experimental test machine started with some simple cyclone trials to see if the products could be separated into light and heavy fractions. This led to the design and build of a system incorporating different types of density separation techniques and equipment: drop out boxes, vacuum and pressurised units; together with means for collecting the separate materials in storage pens. These trial separation units operated by the combined use of gravity (downwards) and counter current airflows (upwards).

The prototype BDS incorporated a range of standard material handling equipment including pneumatic conveying pipe work, rotary valves, a vibratory hopper and an inclined feed conveyor. A dust collector was introduced to enable the monitoring of the production of dust to see if this would be a problem in the operation of this type of equipment and to assist in the future plant design.

Trials were carried out to test and prove the various technologies to see which was the most efficient and to develop the process flow for each of three product size fractions:

- -5mm
- +5mm to -16mm
- +16mm to -50mm.

The trials involved varying such parameters as throughput, feed rate, type of feed and air velocities. When the most efficient equipment and process flows were ascertained it was decided after visual inspection that a finer cut on the lighter combustible materials would be tried for further separation of light plastics and fines.

After the completion of the initial trials the experimental BDS was re configured to provide a continuous process line. Samples of the processed materials were sent away for laboratory analysis to provide information on the physical characteristics. Processing was then carried out on materials from each of the three product size fractions. Further samples were produced for laboratory analysis, burn and gasifier trials.

6.3 Results of the Trials

The main findings of the study are:

- It was seen that the experimental Biomass Density Separator Plant did successfully separate out the heavy material from the light materials, and further separation of plastics from the light materials.

- The separation resulted in a clean sanitised product for each of the three size fractions

- The laboratory results concurred with the visual analysis of the separation in terms of calorific value and ash content.

- Information has been generated for use future plant designs.

- By changing the cut points in the system different qualities of biomass fuel products could be achieved

Details of samples produced and sent for laboratory analysis are contained in Appendix K

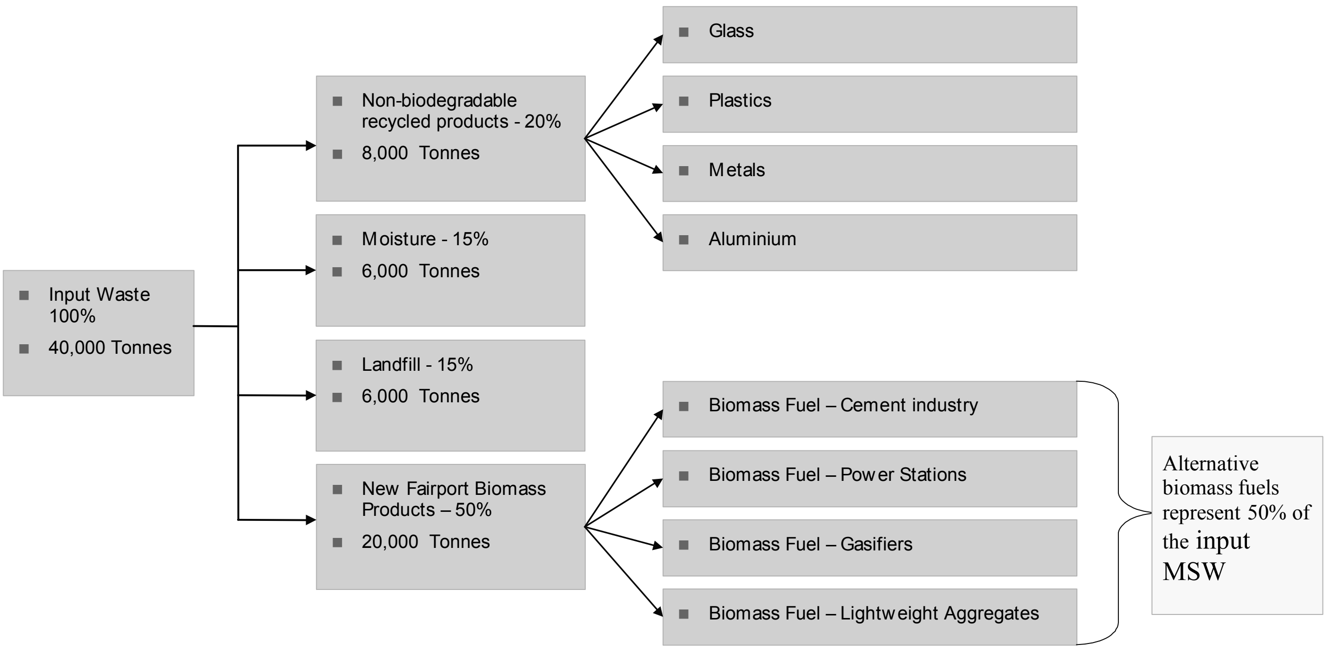
7.0 MARKET EVALUATION REPORT

Waste Strategy

The principal objective of Fairport's Waste Strategy is to divert at least 85% of the incoming MSW (Municipal Solid Waste) stream away from landfill. The Fairport Process recovers usable recyclates such as metals, glass and plastics from the input material and converts the residual biodegradable waste material into a range of new biomass products for which markets have been identified. The Project has recognised the importance and commercial potential of finding sustainable markets for all the products created through this diversion from landfill. **The input waste is seen by Fairport as a raw material for the production of saleable products**

Processed Products.

The following chart details the breakdown of the incoming MSW stream into the outgoing recyclates and fuel type products.



Markets for Fairport Processed Products

Recycled Products

Extensive research has been undertaken to investigate and identify sustainable markets for these products, including biodegradable and non-biodegradable products.

The following table details typical products in this stream and outlines end users where applicable:

PRODUCT DESCRIPTION	APPLICATION	IDENTIFIED ENDUSER	% OUTPUT
Aluminium	Recycle as new product	AlcanUK Plc	1.0%
Ferrous Metals	Recycle as new product	Corus	5.0%
Mixed Glass	Aggregates for construction industry	RMC	4.0%
Mixed Plastics	Feedstock for new plastic products	BP and others	10.0%

With the possible exception of mixed plastic, where markets are still being developed, Fairport is confident that long-term markets exist for all the above non-biodegradable output products.

- The high quality of the recyclates is attracting premium price offers particularly for aluminium and ferrous cans.
- A market for the mixed glass fraction has been identified as an aggregate for the first dressing layer in road making
- Wood, textiles and construction material all have defined and sustainable demand

Process opportunities exist for the treatment of mixed plastics and these are being evaluated

Mixed Plastics

Currently the UK generates around 33 million tonnes of MSW per annum subject to some 3% increase each year. Around 10/12% by weight of this waste stream is mixed plastics. At present it is estimated that only 50k tonnes per annum of mixed plastics are used to produce new plastic products (pallets, garden furniture, re-use as pellets, fibrous materials) in the UK. One issue has been the lack of a sustainable supply of suitable material to allow UK companies to invest further in this area and develop themselves.

The forecast success rate of new technologies in recovering and recycling mixed plastics from the input waste will significantly increase the volume of processed plastic available for re-use.

Fairport's long term strategy is to have markets and products available to exploit this opportunity

Fairport is investigating a range of short term, medium term and long term strategies for finding sustainable markets for mixed plastics. It is estimated that between 10k and 12k tonnes per annum will be recovered from each 100k tonnes per annum Fairport processing facility

Short term strategy
In the short term all mixed plastics could be shipped to countries (such as China or India) specialising in the labour intensive practice of manually separating the mix into defined plastic types. This is not a satisfactory solution and legislation is planned which will significantly increase the regulatory controls on this activity

Medium term strategy
A number of markets have been identified for a plastic 'mix' which excludes PVC. Fairport has used its process engineering expertise to develop a system to remove the PVC fraction. The remaining plastic materials are then suitable for use as a construction aggregate or as a source feedstock for a range of new plastic materials. Fairport will granulate the plastics which will greatly enhance the handling, storage and transport characteristics of these feedstock products

Long term strategy
The treatment of mixed plastic in emerging technologies such as microwaving, pyrolysis or gasification produces oils, gases and a residual char. The secondary processing of these oils and gases will generate a range of new products and markets are already indicating demand for in excess of 1m tonnes per annum of product. Fairport has been working closely with plastics specialists, recyclers, manufacturing companies, universities, and brokers to establish future markets for its mixed plastic stream and are very positive that sustainable markets comprising of a number of different outlets will be identified. To date demand for over 300k tonnes per annum of mixed plastic has been identified

Fairport Refined Renewable Biomass Fuel Products (RRBF)

Fairport has taken a pragmatic approach to the development of this business stream to ensure a balanced spread of risk and the maximisation of the long term opportunities.

Before confirming the design characteristics of its innovative waste technology Fairport undertook a period of market research and the following markets were investigated to identify whether the end users could define a specification for a biomass product whose source feedstock comprised household waste. Fairport then used its process skills to produce a product to meet that client specification. This approach provides Fairport with a significant commercial advantage over all its competitors. Fairport finds a defined market and then produces a product. Its competitors produce a product and then try and sell that product to an unresponsive market. In many cases this latter exercise is a 'wasted' one with the expensively produced product having to be landfilled or at best paid to be disposed of.

The test markets for the Fairport products have been identified as follows:

- As a high quality alternative fuel in a range of industrial boilers and kilns as in the paper and cement industries
- As a renewable biomass fuel and fossil fuel substitute in the power generation industry
- As a fuel in lower capacity energy generating applications providing electricity and heating for schools and hospitals using gasification technology
- As an ingredient in the manufacture of lightweight aggregates and in block making for the construction industry.

Markets for biomass fuel products

The biomass fuel products (produced from MSW) have the potential to become a new sustainable renewable resource and significantly help the UK economy by reducing its dependency on imported fuel alternatives such as olive oil residues, palm oils etc. At the present time potential exists for between 8/10 million tonnes per annum of biomass fuel product within the UK.

The main potential end users of these products in the UK are the 17 coal fired power stations and 13 cement manufacturers, with the production and development of suitable gasifiers being a tangential development to the future available market for RRBF.

Currently RRBF can be used in the following:

- Coal fired power stations @ 10% of station fuel load - up to 3 million tonnes per annum

- Cement Kilns up to 1.2 million tonnes per annum

- Gasifiers up to 1 million tonnes per annum

In the above applications the RRBF is used to generate electricity, by either co-firing with coal, or producing a gas to run a gas fired internal combustion engine that will run a generator, or as an alternative fuel in an industrial boiler.

Power Stations
The specification for a biomass fuel product suitable for mixing with coal in a power station is very narrow. The power generators have incentives under the Renewables Obligation Rules (ROC's) to generate electricity using a proportion of 'non fossil' fuels. Prices for these imported products are currently very high due to the level of demand. Fairport has used the unique capabilities of its newly developed Biomass Density Separator (BDS) to produce a premium product which will meet the ROC's requirements. The BDS will remove all 'contaminants' but in particular the plastics element which causes chlorine emissions problems and is thus barred by the ROC's regulations. None of Fairport's competitors can match this level of product refinement. Commercially it is important that the required certification of the premium product is achieved. The product without certification is still capable of being used by the power station but its value is significantly reduced. At a calorific value of approximately 14000 kj/kg this premium product meets the requirements of the ROC regulations.

Test work on samples of the Fairport product was undertaken by the power generation industry testing house at Ratcliffe on Soar. These tests investigated the operational suitability of the Fairport products as a fuel in a mix with coal in a 10/90 ratio. The test results were very positive and clearly demonstrated the suitability of the product to mix with coal.

Additional test work was carried out on emissions from the products and these were found to be acceptable

The next stage in the commercial development of this business stream is to obtain a classification of the product as an 'approved biomass fuel' and discussions are currently underway with a number of Government agencies

Gasifiers
The market for fuel products for gasifiers is currently small as gasifier manufacturers in the main continue to develop and test their technology.

It is anticipated however that in the next few years demand for gasification technologies and equipment will substantially increase thereby increasing demand for a range of suitable feedstock products. The Fairport product suitable for gasifiers is again at the premium end of the market and will attract a relatively attractive price.

Fairport has conducted trials with a local North West gasifier manufacturer and it is evident from these trials that the Fairport product is ideally suited for this market but technical enhancements are required to the gasifier to improve the commerciality of any supply contract

Cement Industry
Cement manufacturers currently use a variety of exotic materials as fuel products – tyre chips, chicken litter etc and none of these provides a long term sustainable UK alternative. The Fairport RRBF has been tested by three leading cement manufacturers and found to be ideal for use as an alternative fuel product. The definition and composition of the product includes an element of plastics which increases its calorific value to approximately 18000 kj/kg

An added attraction of the cement companies to Fairport is the desired intent of the cement industry to build 'biomass fuel product' production plants on sites adjacent to existing cement plants thus minimising the transportation costs and improving the chances of early planning consent decisions on any such production facilities. In the North West alone capacity exists for the output from at least 5 Fairport 100k tonne per annum waste plants

Markets for other Fairport biomass products

Biomass fines are produced from the biodegradable fraction and can be separated into a biomass fuel product and a residual fines product. This latter product has been successfully tested in the manufacture of a lightweight aggregate, where the Fairport product is mixed with other wastes such as clay and fly ash then fired in a kiln at high temperatures to produce an aggregate which has a 'honeycomb' structure making it as strong as stone but at half the weight. This obviously has many attractions to the construction industry both in the UK and overseas.

The biomass fines product can also be used as a fill material in the lightweight block making industry within the UK.

At present it is thought that the market for fines is:

- Lightweight Aggregate Plants   up to 0.2 million tonnes / annum

- Block Making Plants up to 0.2 million tonnes / annum

8.0 PROJECT CONCLUSIONS and RECOMMENDATIONS

Potential markets for the range of biomass products and recyclates has been identified. This covers a range of biomass fuel products, plastics, ferrous and non-ferrous metals, aggregates and glass; refer to sections 3.5.2, 3.6.5 and 7.0 of this report. The further development of these markets will be prime objective supporting future business proposals.

The project has successfully confirmed the efficacy of the newly developed Fairport process, producing a range of biomass fuel products on a consistent basis within predicted budget.
From this data a mass balance and an energy balance have been produced to assist future plant design and performance specifications; refer to appendix I.
A further opportunity to develop the plant and process to a full sized commercial operation to demonstrate this to the Waste Industry and UK Government is now required.

A detailed environmental impact assessment has been produced and issued covering site, process, and products. The emissions scrubbing unit will be re-designed for future plants to remove the issues with odour and VOC's; refer to EIA report in appendix G.

Data on the trials, process, equipment, emissions monitoring, products and waste management and control has been collected and collated and is being used in commercial considerations and future plant design; refer to section 3.8 of this report.

A procedure for the certification of alternative renewable energy fuels is currently being drawn up and evaluated by various government bodies; refer to section 4.6 of this report.

The trials program has successfully proven that the plant and process produces RRBF and other materials for recycling. The next phase of the project will be to design and build a full scale commercial plant that will create up to 30 jobs per plant.

The trials programme successfully produced an alternative non-fossil fuel, with long-term storage (6 weeks) capabilities, suitable for pelletising to increase handling and transportation at a commercially acceptable cost; refer to sections 3.5, 3.6 and 7.0 of this report.

The trials programme has been a major step forward in processing biodegradable waste. This took the initial pilot study of processing 250 kg/hour to a full sized, single line processor, commercially operated, capable of processing 6 to 8 tonnes per hour; including processing, separation and segregation and producing a range of output products.

The trials program has proven the development and introduction of a new environmentally acceptable and sustainable energy source.

With the introduction of the above energy source we have made a positive impact in the balance of trade due to lower reliance's on importation of coal and other alternative fuel products.

The potential for developing the process, plant and products for export is huge, particularly the technology and plant operation to other countries that have issues with waste management. This will be explored in more detail in support of future business opportunities.

In the 1990's the Government's concerns shifted from fossil fuel depletion to concerns about global warming, and controlling the emission of greenhouse gasses. The UK's international undertaking, under the Kyoto Protocol (agreed in 1997) was to reduce a basket of six greenhouse gases by 12.5% below 1990 levels in the period 2008 – 2012 (EU burden sharing agreement).

The development of a sustainable RRBF product has presented the opportunity of meeting with Government to review and revise policy and set new standards for renewable energy and waste management issues. At present these issues are still in discussion and the results of this has created a widespread interest and debate on the subject.

Trials on co-milling and co-firing RRBF in a utility boiler are very positive confirming that the RRBF is suitable for this purpose. Further investigations in respect of EA regulations are still to be completed; refer to section 4.3 of this report.

Trials using the RRBF as a fuel for gasification proved successful, with the production of a suitable gas for use with a gas fired internal combustion engine; refer to section 4.4 of this report.

Trails on the use of RBF as an alternative fuel for the use in Cement kilns have proved successful; refer to section 4.5 of this report.

The plant constructed at Adlington was a full size single process line. It was understood to be for a short duration, future plant designs would not use stand alone hired in generators or gas supplies, but mains power and natural gas, both at a lower cost.

The development of the Fairport Biomass Density Separator is a major step forward in the refinement of products to meet individual end user specifications. It is fundamental to the success of the project in satisfying stringent legislative and market requirements. It can be seen from the results of the trials that the separation processes removed the vast majority of heavy non combustible items for re-use as other products, together with further refinement resulting in the removal of varying amounts of impurities and plastics from the end products. Further development should be conducted to producing a full sized separation plant; refer to section 6.0 of this report.

During the trials programme a number of designs were modified to improve process efficiency. This covered modifications to chutes, hoppers, conveyors, and feeders, drum internals and seals. All these points are to be incorporated in future plant designs.

The trials programme is seen to be very successful in achieving the key objectives of the project. It is considered a necessity to take this forward to a commercial operation to support the waste management activities and the provision of alternative fuel sources to help meet UK legislation and targets.

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