

SECTION 5

SMALL SCALE POWER GENERATION AND CHP

PROJECT SUMMARY LISTING

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DEVELOPMENT OF A SMALL-SCALE BIOMASS CHP SYSTEM

Sustainable Energy Ltd

OBJECTIVES

- To develop and demonstrate a compact entrained flow biomass gasifier, using a swirling flow reactor to suspend and react pulverised biomass into a low tar and particle content wood gas, suitable for fuelling a CHP engine, with minimal post processing equipment for gas cleaning.

SUMMARY

The objectives of this project were successfully met by demonstrating a novel prototype small-scale biomass CHP system. A compact biomass gasifier, adopting swirling flow to incorporate particle separation within the reaction produced wood gas to fuel a CHP engine, with minimal post processing equipment for gas cleaning. The technical objectives were devised to reduce the capital equipment costs of biomass CHP systems, and thus to enhance the economics of small-scale biomass heat and power projects using this technology.

The research and development aims were completed successfully with a wood gas, of calorific value 5.7MJ/kg, produced which was suitable for fuelling a CHP engine.

COST

The total cost of this project was £78,750 with the Department of Trade and Industry (DTI) contributing £37,563 and Sustainable Energy Ltd the balance.

DURATION

18 months – June 2000 to December 2001.

BACKGROUND

The low energy density of raw biomass resource means much higher levels of transportation are required to move fuel to the sites for use, therefore larger power stations that consume biomass from wide areas will induce pressures on rural infrastructure, namely roads. Small-scale biomass systems for on-site generation sited within small catchment areas of biomass resources should, therefore, have significantly lower impact on local surroundings.

Sustainable Energy Ltd (SE) initiated their biomass research programme with a project funded by the SMART Award scheme to develop a small scale pyrolyser based on cyclonic flow. Stemming from work on this project and a working relationship with Cardiff University the concept of biomass gasification for CHP generation was

created. Bringing together fundamentals of SE pyrolyser and findings from a biomass gasifier developed at Cardiff University, resulted in the concept of the swirl flow gasifier CHP system.

THE WORK PROGRAMME

This project developed a small-scale biomass system to convert biomass in the form of sawdust into electricity and heat.

The technical objectives were designed to achieve a significant reduction of capital equipment costs, thus enhancing the economics of small-scale biomass heat and power projects using this technology compared with other commercial biomass gasifiers.

The project focused around a swirling flow gasifier, which was driven by air injected at atmospheric pressure conditions. The gasifier was sized to process 40kg/hr of sawdust and generate 45kW of electricity and 100kW of heat. The swirling flow within the gasifier incorporated two stages of particle separation in a rapid entrained flow reaction. The result was a low calorific value wood gas of low tar and particle content. The system included further gas cleaning, to separate any fine ash particles, moisture and tars from the wood gas, before firing a diesel Internal Combustion (IC) engine converted to spark ignition.

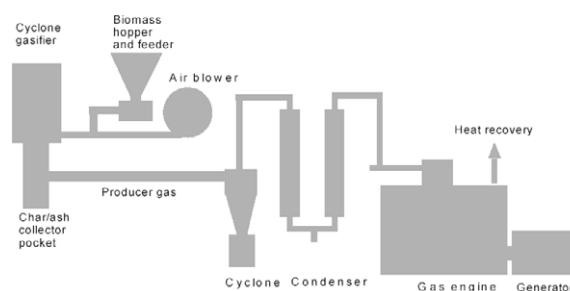


Figure1 Schematic of the experimental set up

RESULTS

Over 30 iterations of gasifier design alone were carried out in development of the biomass CHP system as presented in the report. A significant level of IPR was developed which remains commercially sensitive, therefore, the report only presents the experimental results of the final system. The hours of operational experience with the gasifier was >100 hours, with engine operation on the wood gas for 15 – 20 hours.

The gasifier was successfully tested at biomass feed rates of 40kg/hr, however, due to problems with the 45kWe CHP engine the gasification system was demonstrated using a smaller 12.5kWe IC engine with the gasifier turned down to 50%. At 20kg/hr the gasifier produced 73kW of wood gas, of this 33kW was used to feed the IC engine and generate 10kW of electricity, the remaining 40kW was flared off. The gasification efficiency was calculated to be 75%, which subject to the amount of wood gas used to power the IC engine gave a total electrical conversion efficiency of 22.7% (wood in to electricity out) and a wood gas to electrical efficiency of 30%.

Several hours of operation were achieved with the engine running on wood gas but within the scope of the project the assessment of the long-term effects of wood gas on the engine was not carried out.

CONCLUSIONS

- A compact biomass gasifier based on entrained swirling flow gasification was developed and proven to provide an efficient method of conversion of sawdust into wood gas. The system benefited from reduction of 20 – 30 times in physical size when compared to a typical downdraft gasifier, this will reduce equipment costs.
- The gasifier proved to be very efficient, offering 75% energy conversion from wood to gas.
- The gasifier incorporates two stages of particle separation within the reactor, which collected a large part (3.9%) of the ash and char from the gas leaving only 0.1% of sub 10µm particles to be separated in a high efficiency cyclone. This also offers reduction in cost of particle separation equipment.
- Compared with air gasification systems, the gasifier developed in this project produced a good wood gas containing 5.7MJ/kg.
- The operational experiences of the prototype biomass CHP system found that due to the stable operational characteristics and the rapid response of the gasifier to the engine, automated control of the process could be simply applied using a PLC system.

- The spark ignition IC engine was run successfully on the wood gas with a very small trace (1% - 2%) of pilot gas. It is thought that this pilot gas could be entirely removed with further development work.

Therefore a significant reduction of capital equipment costs can be achieved over current biomass conversion technologies, thus enhancing the economics of small-scale heat and power systems. The system has been successfully proven, but is not suitable in its current form for commercial use.

Commercialisation of the technology is possible once steps one and two from Section 8 of the report have been completed. The predicted system cost already compares favourably to the costs of competing downdraft gasification systems, however, it is proposed that further design for cost reduction will be undertaken and will focus on reducing engine costs.

POTENTIAL FOR FUTURE DEVELOPMENT

The following recommendations are proposed in the form of further projects, each covering specific aims of the development of biomass energy systems based on the swirling flow gasifier.

1. Connecting the gasifier back up to the 45kWe CHP engine, design and integrate automated feeding system, simple control and monitoring system and run for continuous operation trials. Objectives of optimisation of system efficiency, testing of contaminants to engine oil and fine tuning of the system.

2. Develop pre-production unit incorporating design for low cost manufacture. Commissioning and commercial demonstration of the small-scale biomass CHP system.
3. Pressurise the gasification process and secondary separation cyclone and fire clean wood gas through a secondary combustor and through a gas turbine for heat and power generation.
4. Gasification of other pulverised biomass feed stocks with full gas and by-product analysis. Fuels to be used include, chicken litter, dried food wastes and other segregated waste streams.

BIOMASS COMBUSTION GAS TURBINE CHP

Talbot's Heating Limited

OBJECTIVES

- To integrate low cost micro-turbines with the flexibility of biomass combustion, to provide a simple low cost solution and open a new market for biomass combustion generation.

SUMMARY

Alternative electricity generation methods to steam-cycle technologies are currently being studied, and these include gasification and direct firing of gas turbines.

There is a large demand for simple highly efficient biomass generators under 1MW. The more efficient the biomass to electrical energy system is, the easier it will be to justify and promote biomass and energy crops projects.

The project began by reviewing biomass indirect firing of a micro-turbine. Then a computerised model of the system was produced to allow evaluation of the different components, including heat exchanger design and choice of turbine. After the evaluation stage a test rig was manufactured and commissioned in order to carry out trials.

The project successfully provided proof of principle and work will continue to optimise the system.

COST

The total cost of this project was £123,900 with the Department of Trade and Industry (DTI) contributing £60,900 and Talbot's Heating Ltd the balance.

DURATION

18 months – August 2000 to February 2002

BACKGROUND

Generation of electricity from biomass is not common in the UK at the moment. The traditional method of generating electricity from biomass involves producing steam by passing the hot biomass combustion gasses through a waste heat steam boiler. This steam is then used to drive a steam engine or turbine generator. Steam based systems provide low fuel to electrical output efficiency due to the dumping of heat in the condensation phase, as a result fuel feed rates high and the electric outputs are low.

The economics of small-scale steam based generation using biomass

combustion are hard to justify under 1MW due to low efficiencies and high capital costs. Steam is easier to justify when there is a use for the excess heat (CHP), but this relies on a constant demand for heat when the system is generating. Steam engine tends to have higher efficiencies, but costs are high compared to turbines.

Current small-scale biomass combustion CHP systems are based on raising steam to drive a steam engine or turbine. This system has poor efficiency at such small-scale (30kW_e), with typical efficiencies of 6-8%. Capital costs per kW_e of generation capacity are also high due to complex systems and low efficiencies, typically £6500 per kW_e. Commercial opportunities for this system are small. To be economically viable this system requires very high electricity prices, a constant need for heat and an abundance of free or waste fuel.

To assist with the renewables obligation in way that will be economically viable, a biomass combustion generation system is needed to provide high efficiency at a price the market can afford.

Talbott's heating are developing a small-scale biomass combustion CHP system based on indirect firing of a micro gas turbine.

THE WORK PROGRAMME

The project began by reviewing biomass indirect firing of a micro-turbine. Then a computerised model of the system was produced to allow evaluation of the different components, including heat exchanger design and choice of turbine. After the evaluation stage a test rig was manufactured and commissioned in

order to carry out trials. The following experiments were performed:

1. Initial Heat Exchanger performance test

Eight channels of temperature recordings were captured as the combustor was lit, warmed up and run for four hours, then shut down. Performance was compared with design.

2. Second Heat Exchanger performance test after modification

The first experiment was repeated, after performance improving modifications were completed. Again eight channels of temperature recordings were captured as the combustor was lit, warmed up and run for four hours, then shut down. Performance was compared with design and experiment 1.

3. Micro Gas Turbine Performance Test

This test was conducted to provide a benchmark and an understanding of the performance of TG50 micro-turbine. The turbine entry temperature is higher than the Biomass Generator system, hence higher power output.

4. Initial Biomass Generator performance test

This test was to initial data on system performance and to define starting procedures. Eight channels of temperature recording were captured as the combustor was lit, warmed up and run for eight hours then shut down. Compressor air was initially off, then run up to 34,000rpm for approximately 15 minutes. Data was recorded in real time, with measurements taken every 30 seconds, with heat transferred in kW. The ModBus system logged the turbine operating conditions.

5. Second Biomass Generator performance test after modifications

This test was aimed at accelerating the turbine up to its normal running speed of 100,000rpm. Also the systems performance due to heat exchanger modifications was observed. Eight channels of temperature recording were captured as the combustor was lit, warmed up and run for eight hours, then shut down. Compressor air was initially off, and then run up to various speeds. At 42,000rpm and 700°C a unit began a strong acceleration up to its operational speed. Thermal performance from the heat exchanger was good, with temperatures rising to a maximum 728°C under full flow conditions. Data was recorded in real time, with measurements taken every 30 seconds, with heat transferred in kW. The ModBus system logged the turbine operating conditions.

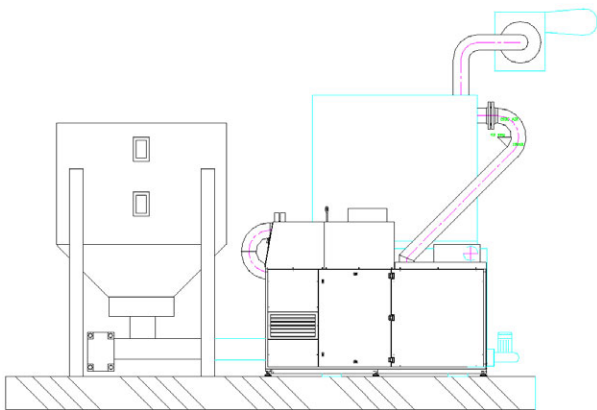


Figure 1 General arrangement of the biomass generator system

RESULTS

- The system achieved turbine generation speed with steady acceleration, although much slower than conventional gas turbines. Heat exchanger performance increased with turbine speed. Temperatures and mass flows are critical for turbine

acceleration. Higher thermal inertia is required to quickly accelerate passed turbine critical speeds. The heat exchanger has proved the principle works, and should now be developed to increase its efficiency and life cycle.

- From the test data the predicted power generated from the Biomass Combustion Turbine was 30kW.
- Although the system was still at an early stage of development, and could benefit from an increase in both combustor and heat exchanger size, capital equipment costs for this 30kW_e prototype are around £2,500 per kW_e. Comparing this with our current steam based 50kW_e CHP system with an electrical efficiency of 8% and cost of £6,455 per kW_e, this represents a great leap forward.
- Commercial prospects for this technology are good with existing heat only installation, it is predicted a large number will be interested in producing electric from their existing waste fuel supplies. The 30kW_e unit could provide an offset to normal base load of 250kW_e average to wood working factories. With electric being purchased at 5p/kW this would save £1.50 per hour. operating this unit for 8000 hours per year will save £12,000, ROC will add another 3p/kW (although sold on the open market may yield 5p/kW), this adds a further £7,200. Therefore the payback period can be calculated to four years. Heat output will make the system more attractive as well, by cutting gas or oil costs. Larger units with higher efficiencies and

lower costs per kW will of course, provide much faster pay back, a 250kW_e system is expected to have a payback period of just 2.5 years.

CONCLUSIONS

- Biomass Combustion Turbine project has successfully provided proof of principle.
- Biomass Micro Gas Turbine acceleration is slower than conventional gas turbines.
- The system has demonstrated it is possible to produce 26-34kW_e of electrical renewable energy plus recoverable thermal energy.
- Approximately 100-150kW of high-grade thermal energy is available for simple conversion to heating water or air.
- Low heat losses results in overall system efficiency of between 80-85%
- Electrical efficiency is 17% and will rise with further development.

POTENTIAL FOR FUTURE DEVELOPMENT

It is recommended:

- To run the system for a period of one year to provide data on the long term effects on materials at the high temperatures.
- Improve the overall cycle efficiency.

- The biomass combustor should be re-designed to incorporate the higher air return temperatures and volume flow rates, other improvements could be incorporated inline with our experience of this system.
- To utilise waste heat from the system - this could be used in heating and cooling applications, thus making an efficient biomass fired Co-gen and Tri-gen system.

COST AND OPERATIONAL ACCEPTABILITY IMPROVEMENTS TO GASIFIERS

Biomass Engineering Ltd

OBJECTIVES

- To investigate the benefits of using a ceramic filtration system to remove organic contaminants in the exit gases (generally referred to as tar) from biomass gasification processes.

SUMMARY

Biomass Engineering Ltd has operated two gasifiers on their site for five years. One of these is now operating as a commercial unit (75kWe gross, 55-65kWe net output) in Northern Ireland (in the Ballymena ECOS Millennium Centre, where a variety of sawmill wastes and other woods have been used). Based on the tar and particulate sampling performed under contract by CRE, very low tar levels were measured, in the raw gas of 11mg/Nm³, there were particulates of <50 mg/Nm³ after the first cyclone. The very high tar destruction level also meant that the gas calorific value (CV) was more acceptable – 5.2MJ/Nm³ (LHV basis).

Biomass Engineering Ltd decided to utilise this information in the operation of their remaining installation at their works (by drastically simplifying the gas conditioning system by using a back-pulsable ceramic filtration system to remove the particulates and trace

organics from the gas). This was then followed by gas cooling to remove water and final filtration before reaching the gas engine. The benefits of using a ceramic filtration system are continuous operation, simplified system and lower installed and operational costs.

Mass and energy balances for the overall gasification suggest a gasifier efficiency of typically 80% (LHV basis) and overall system efficiency to electricity of 25% or more.

A techno-economic assessment of the original wet scrubbing system and the new dry filtration system has shown that significant cost savings (up to 12%) can be made, with net electricity production costs of 2.4p/kWh for a 293kWe output system. Use of the dry filtration system in a CHP scenario can reduce costs by 16-25%, depending on the feedstock cost and the power output required.

Further work is required to optimise the operational parameters of the filters, which will be carried out later this year.

COST

The total cost of this project was £54,500, with the Department of Trade and Industry (DTI) contributing £21,850

and Biomass Engineering Ltd the balance.

DURATION

18 months – September 2000 to March 2002

BACKGROUND

Biomass gasification processes generate organic contaminants in the exit gases that are generally referred to as tar. Before use of the gases in a boiler, engine or turbine, particulate matter and organic tar must be removed (or reduced to a level that is acceptable to end user requirements). The specifications vary from manufacturer to manufacturer, and careful matching of the technology and the end user is required. In addition, the actual determination of the level of 'tars' is still under development.

The subsequent removal of gasification tars from the process gas has led to the development and selection of a wide range of gas cleaning and solids removal technologies. Small-scale users generally do not appreciate what is happening in the gasification field at large and, quite often, there is a lag phase when new small-scale technologies are slowly developed. At present, there are several gasification technologies under development in the UK for the production of low-medium value heating gas for subsequent use in an engine or turbine.

THE WORK PROGRAMME

Two main areas of work were undertaken:

1. Investigation of the effectiveness of a dry ceramic filtration system.

2. Investigation into the costs of the new system.

Based on experience with a similar system, Biomass Engineering Ltd ordered a small back-pulsable ceramic filter system from CFI Ltd, to be fitted to the company's second gasifier. CFI had prior experience in biomass gasification filtration systems in the UK and in other European countries. There were some considerable delays in obtaining the unit and the ceramic filter elements.

The filtration test unit is designed to handle all of the flow of gas from the gasifier at its outlet temperature of 200-400°C. Nine elements are held in the housing, with six elements online and three being periodically back-pulsed (to remove accumulated particulates consisting of char and ash). Differential pressure measurement is taken over the filter elements, and the readings are continuously monitored. When the pressure drop reaches a setpoint, three of the filters are backpulsed with clean producer gas. The dislodged char and ash drops down into the collection drum. The six filters are capable of handling the increased gas flow for the brief backpulse time. The three groups of three filters are back-pulsed in sequence, controlled by independent valves. Madison Filters supplied the elements, as recommended by USF Schumacher (now Pall Schumacher).

RESULTS

The gasifier was rebuilt and relocated, and a new gas engine has also been installed. Mass and energy balances for the overall gasification are presented in the report, highlighting a gasifier efficiency of typically 80% (LHV basis) and overall system efficiency to electricity of 25% or more.

Locally available pallet wood and wood wastes from spruce were used as feedstock. Gas samples were taken for analysis and operation of the filtration unit carried out.

No testing of tars and particulate levels has been done at this time, but experience with a similar system was the motivation for this project.

A techno-economic assessment of the original wet scrubbing system and the new dry filtration system has shown that significant cost savings up to 12% can be made, with net electricity production costs of 2.4p/kWh for a 293kWe output system. Use of the dry filtration system in a CHP scenario can reduce costs by 16-25%, depending on the feedstock cost and the power output required.

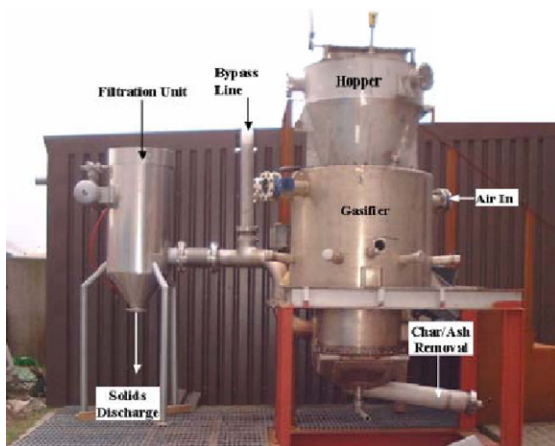


Figure 1 Gasifier and test filtration unit

CONCLUSIONS

- The CFI filter system has been used satisfactorily to produce a clean gas, which has been used in an Iveco-Aifo engine.
- Modifications have been made to the back-pulse sequence and duration of the back-pulse to prevent nitrogen being blown back into the gasifier.

- Further test work will modify the gasifier to allow for semi-continuous running and also replace the current filter system.
- A techno-economic assessment of the original wet system and the new dry filtration system has demonstrated that there are significant cost savings to be made.
- The net electricity production cost the dry filtration system to produce 293kWe is 2.4p/kWh. For a CHP system, this cost drops to 1.8p/kWh, for a zero cost feedstock.
- The dry filtration system has distinct advantages and allows continuous running with automatic solids removal and recovery.

POTENTIAL FOR FUTURE DEVELOPMENT

The following recommendations are made:

- Modify filter system and carry out full monitoring programme on contaminants before and after the filter system.
- Characterise the particle recovered and assess filter performance.
- Modify gasifier to allow semi-continuous feeding and therefore increase run times.
- Remove gas fan and install air fan to pressurise the gasifier and therefore improve smooth operation of the gasifier and filter system.
- Carry out long-term engine testing on the clean gas from the filter system.

DEVELOPMENT OF A MICRO-TURBINE PLANT TO RUN ON GASIFIER PRODUCER GAS

Biomass Engineering Ltd (with Advantica Technologies Ltd)

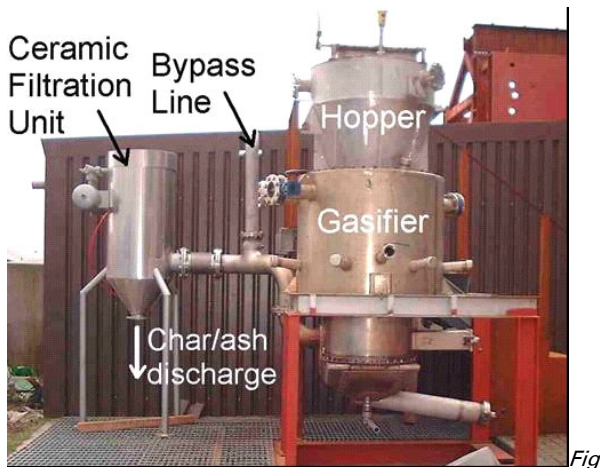


Figure 1. Gasifier+filter at Newton-le-Willows

SUMMARY

Biomass Engineering Ltd has succeeded in developing a downdraft gasifier capable of producing a clean, very low tar, low particulate gas of consistent calorific value. The gas has been used in different engines and from a range of feedstocks.

For very high quality gas, micro-turbines can be considered as another possibility as a prime mover for power generation. To this end, the project was concerned with the coupling of an existing test gasifier to a Capstone micro-turbine, model 330. Initial testing took place at Advantica's research laboratories in Loughborough. Tests were carried out by passing synthetic producer gas over catalyst blocks to check the flammability of the gases, which proved that the gases could be easily ignited with very low slippage of CH_4 at less than 2.5wt%. Operation of the Capstone micro gas turbine on 100% producer gas was achieved successfully at a net electrical output of 5.5kWe with low NO_x emissions (<2ppm).

The micro-turbine was then removed and re-commissioned on site at Biomass Engineering Ltd facilities. 350 hours of operation have been obtained on producer gas and over 800 hours on natural gas. There have been

OBJECTIVES

- Demonstrate practicality of continuous supply of consistent quality of producer gas to meet the requirements of a micro-turbine/wood fuelled gasifier CHP system.
- Achieve 1000-2000 operational hours with the gasifier coupled to the combustor (including control rig) to provide data for a commercial system, operating on a variety of wood residue fuels.
- Determine potential of small-scale micro-turbine and generate data to scale up to larger micro-turbines (30 - 300kWe).
- Complete a techno-economic assessment of the overall gasifier+ micro-turbine.

problems in start-up, due to limited access to the control software for the turbine and late delivery of the gas compressor for the micro-turbine. Gas emissions and performance of the micro-turbine have been satisfactory; however, more long duration testing of the micro-turbine is required to ensure optimal performance. Use of producer gas achieved similar very low emission levels, using a ceramic filtration system to remove particulates and trace tars.

A techno-economic assessment of the complete biomass gasification system from delivered wood chip to electricity and heat output has been completed. A range of biomass inputs was from 50-250kg/h (prepared material), net electrical output 21-108kWe. The net electricity production costs were excessively high, ranging from > 65p/kWh at 11kWe output to 22p/kWh at 108kWe net output, as the micro-turbine and gas compressor typically comprised over 45-59% of the installed costs. All costs taking wood fuel cost of £25/t delivered to site.

Micro-turbines of 30kWe do not offer any economy of scale in gasification systems; therefore more work is required on 'larger' 250kWe turbines, such as those offered by Ingersoll Rand to assess technical and economic performance.

COST

The total cost of this project was £545,000 with the Department of Trade and Industry (DTI) contributing £272,386 and Biomass Engineering Ltd the balance.

DURATION

24 months – January 2002 to January 2004

BACKGROUND

Biomass gasification processes generate organic contaminants in the exit gases that are generally referred to as tar. Before use of the gases in a boiler, engine or turbine, particulate matter and the organic tar must be removed, or reduced to a level that is acceptable to end user requirements. The specifications vary from manufacturer to manufacturer and careful matching of the technology and the end user is required. In addition, the actual determination of the level of 'tars' is still under development.

One of the most significant hurdles leading to the development and subsequent scale up of biomass gasification is gas cleaning for particulate and organic contaminant removal prior to use in power generation applications. Many of the emerging technologies in the UK are small-scale and therefore the end user requirements in terms of gas quality will be strict. Typically, the tar levels are significant from small-scale gasifiers, due to poor design and feedstock specification. Biomass Engineering Ltd has, however, overcome the apparent 'tar' problem by careful control of the gasifier reduction zone and smooth continuous gasifier operation resulting in tar levels of 11mg/Nm³ in the raw gas. By achieving such low tar levels, the gas conditioning system can be greatly simplified and significant cost savings made. To this end, a small back-pulsable ceramic filtration system was planned to remove particulates and trace organics, leaving a tar and particulate free gas.

Biomass Engineering Ltd has successfully operated a test gasifier at Newton-le-Willows with a ceramic filter system and have achieved thousands of hours of operation on a

Perkins Elmer engine and an Iveco engine, both solely on producer gas (ref. B/U1/00677/REP, URN 03/685).

The planned programme of work was:

1. Initial testing by Advantica of a synthetic producer gas over a catalyst system and in the Capstone C-330 micro gas turbine (MGT).
2. Preparation of the gasification system at Biomass Engineering Ltd and process modifications.
3. Installation and testing of the MGT at Biomass Engineering Ltd.
4. Techno-economic assessment of the trials at Biomass Engineering Ltd and cost projections for systems from 50-250kg/h fuel input.

An existing 80kWe gasifier was used. The gasifier nominal throughput is 55-60kg/h of prepared wood and power outputs of up to 80kWe on a gas engine have been achieved. The gasifier is a throated downdraft gasifier, which is refractory cast and has tuyeres equidistant above the reduction zone. Biomass is fed in semi-continuously every 1-2 hours using a high speed belt conveyor, allowing regular refilling of the unit without interrupting consistent gas production. A ceramic filter system was used to remove particulates and trace tars. The ceramic filtration test unit can handle up to 50 Nm³/h of producer gas – the nominal gas flow from the gasifier is ~ 150 Nm³/h on wood. This gas flow from the gasifier is more than sufficient for the operation of the Capstone micro-turbine, therefore the bulk of the gas is passed through the wet scrubbing unit prior to being flared. The use of ceramic filtration offers the advantages of a continuous process, which is self-cleaning and therefore lowers maintenance costs. An ultra-clean gas suited for a micro-turbine can be

produced. Unfortunately, there is little long-term experience in the UK or world-wide on the operation of micro-turbines on producer gas.

The Capstone Model C-330 used in the test work has an electrical efficiency of 26± 2% and requires a gas compressor and a heat exchanger if it is to be operated in CHP mode. For the purposes of this work, no heat recovery was made.

The initial task in the contract was to assess the viability of operation of the microturbine on producer gas, and whether indirect or direct firing of the micro-turbine was possible. To this end, the two tasks of Advantica were:

- Trials of synthetic producer gas/air mixtures over a commercial oxidation catalyst.
- Test work on micro-turbine operation with synthetic producer gas to a specification provided by Biomass Engineering Ltd.

A catalytic test rig was used to test various air/fuel mixtures over a monolith catalyst to assess the viability of fuel combustion at low temperatures. The synthetic producer gas was fed into a stream of compressed air at a ratio approximating to an ideal of 9-11:1 air:producer gas by volume. The ideal ratio was calculated to be the ideal mixture for producer gas of this specification, whilst maintaining the same mass flow rate per kW generated through the micro-turbine when fuelled with natural gas. This air-producer gas mixture was fed to a top cylindrical section containing an electrical heater, which simulated the effect of a heat recuperation system that would typically be installed within a micro-turbine system.

The pre-heated air-gas mixture then flowed through the lower unheated

catalyst modules, within which were located upstream and downstream thermocouples, T_u and T_d . The emerging combustion products were fed to an exhaust collection system, which also had a gas sampling line fed to another gas species analyser. The catalysis modules were a modified 3-way exhaust catalyst, based on a system previously developed for natural gas vehicle engines.

The gas mixture used in the trials had a very similar composition to the product gas from the Biomass Engineering Ltd test gasifier, with a LHV of $5.2\text{MJ}/\text{Nm}^3$.

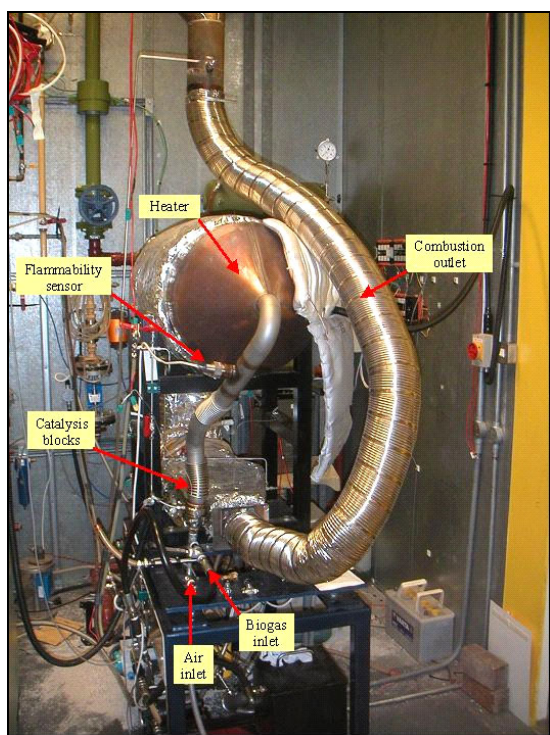


Figure 2. Advantica catalytic test rig (*courtesy of Advantica Technologies Ltd.)

OPERATION AND RESULTS

Operation and Results from the Advantica catalytic rig

Several trials were carried out at different fuel/air ratios and preheat temperatures from $150\text{--}250^\circ\text{C}$. The temperature rise across the catalyst block was measured continuously in conjunction with the inlet and exit gas compositions. The air producer gas mixtures burned very readily over the blocks and a set of experiments to measure the effects of temperature in the blocks and preheat temperatures was carried out. Methane proved the most resistant to oxidation, but the CO and H_2 and were completely oxidised.

It was observed that the unoxidised methane fraction inverse-correlated with the temperature increase between the upstream and downstream catalyst module thermocouples. Whilst the average methane level in the combustion outlet of $0.061\text{ vol}\%$ was not high in an absolute sense, when the dilution of the fuel in air was taken into account, and the relatively small fraction of methane in the producer gas fuel source was allowed for, this measurement indicated that over 28% of the methane input to the catalyst module remained unoxidised. Hence it was decided to investigate how this fraction varied with pre-heat temperature. After some optimisation, a preheat temperature of 260°C was used and measurements made. The average level of methane in the combustion outlet stream at stable temperature was found to be 0.004 \% v/v , this being the lowest methane result obtained. The average increase in temperature between the catalyst thermocouples was 219°C . The fraction of unoxidised methane input was 2.33% .

Operation and Results of the Capstone MGT at Advantica

A range of tests was carried out in order to make the micro-turbine suitable for use on LCV gas. The exact test methods are not detailed here, but the findings and their actions are noted below. Nine runs were carried out, the main difficulty being the switchover from natural gas to producer without causing the MGT to report a fault and shutdown.

The problem of the main fuel valve control dynamic range (termed valve headroom in the remainder of this report) and its ability to keep the fuel supply within the required demand range was an issue that had been identified as a threat to the success of the study prior to test commencement, and it had been noted that it was possible to convert the micro-turbine to low CV operation. This option had been investigated but would have imposed unacceptably long lead times prior to project commencement. Since no flow measurement devices had been incorporated into the simple fuel delivery system, it was not possible to assess the flow rate demand prior to system shut down.

- The turbine would not start up solely on producer gas and a control regime of switching from 100% NG to 100% PG was required. As a consequence of this 'blending', mixing of the gases was required, which caused operational problems with the control valving and the micro-turbine control software.
- The gas inlet lines had to be increased in size to accommodate the increased volume of producer gas required.

- Net electrical output was limited to 5kWe due to the constraints imposed by the gas discharge rate from the gas cylinders.
- Pre-mixing of the natural gas and producer gas could cause oscillations in the main fuel valve if not properly mixed, leading to premature shutdown.
- The gas turbine could be successfully switched over to 100% producer gas with stable turbine operation.
- Average turbine deration at 5kWe output was 52% (LHV basis), fuel LHV 4.4MJ/kg, estimated electrical efficiency of 17-18%.
- The MGT efficiency drops off significantly at low electrical outputs, dropping to 16-17% at 5-8kWe output.
- Emissions from the MGT were very acceptable with consistently low levels of NO_x, CO_x and CH₄. Typical values were 2ppm NO_x, CO between 50 and 80 ppm and CO₂ of 2.32 to 2.42 % and CH₄ of 16-25 ppm.

The work of Advantica clearly demonstrated that the Capstone MGT could be operate on producer gas, even although the turbine had not been modified, however, with a deration of 52% and operating a low electrical output, further work would be required to improve the fuel switching systems and obtain a modified LCV fuel Capstone MGT.



Figure 3. Capstone C-330 at Biomass Eng. Ltd.

Operation and Results of the Capstone MGT at Biomass Engineering Ltd.

The micro-turbine was decommissioned in 2002 and then delivered to Biomass Engineering Ltd in October 2002. It had been originally intended that Advantica would loan their gas compressor to Biomass Engineering Ltd for use, however, this turned out not to be possible. Due to the nature of the producer gas several compressor companies would not supply a unit. CompAir agreed to supply a suitable natural gas compressor, designed for such applications. Unfortunately the delivery of the second gas compressor was significantly delayed, which had an adverse impact on the operation of the MGT.

The initial delivered compressor in early 2003 had various mechanical faults, which meant that initial trials at Biomass Engineering Ltd using producer gas led to very unsafe conditions in its operation.

Subsequent to the installation of the MGT, the pipework configuration for the gasifier was altered to allow a portion of the gas to be sent through a wet scrubbing system prior to flare and the balance through the ceramic

filter system prior to cooling and delivery to the gas compressor.

Due to lengthy delays in obtaining the correct compressor, the planned experimental program of over a thousand hours of operation and runs of 24 hours per day could not be achieved. The replacement gas compressor was delivered and installed in late September 2003. Due to other project commitments, which had not been foreseen at the start of the contract (an order from the British Leather Corporation for a 100kWth leather waste gasifier in June 2003), operation of the gas compressor and micro-turbine could not start until late October 2003.

The operation of the complete gasification system through to the gas compressor then MGT was generally very smooth and from fuel ignition to clean gas production was achieved in approximately five minutes. Once the process was fully operational, over the five month period of running, no problems were experienced on the gasification part of the plant. During this period on a daily basis a total of three personnel were running, operating the controls of the process and monitoring the performance data and power generation. The general tasks required by the personnel were:- wood fuel feed to conveyor system, gasification ignition, manual valve change over, ash residue removal and data monitoring.

The MGT once installed with the gas compressor was re-commissioned on natural gas. This brought to our attention some of the sensitivities within the MGT. If the MGT detects fluctuations in the local electricity grid to which it is supplying electricity, the MGT will regularly 'trip' and shutdown. It was observed that when running on natural gas, or producer gas, the MGT

would shutdown, sometimes after a few minutes operation. It was therefore not possible to leave the MGT unattended during operation on producer gas.

One of the main problems in the supply of the clean producer gas was the switching from natural gas to producer gas. Within the MGT mechanical gas flow pipework control was fitted a large volume, diameter gas inlet manifold valve, generally used on low CV, methane sites, that enables larger volumes of producer gas to be utilised. This however generated further complications on the electrical control detection regime, showing a further fault '6006' again shutting down the MGT. Fault detection '6006' is read as a lack of fuel availability, demand, which was the opposite of the actual detection as the MGT programming was technically miss registering the problem. On assessment of the fault by the turbine control engineer, the programming software could not be amended to suit the new valve parameters.

The test campaign therefore resulted in only 350 hours operation on the MGT on producer gas, but over 850 hours on natural gas. The real-time man-hours assigned to the operation, running of the project, taking into account the constant shutting down of the MGT was over 2200 man hours to achieve the sum total of 1200 actual MGT generating hours.

A techno-economic assessment of a biomass gasification+micro-turbine for power generation was carried out. As compared with a gas engine system, the net electricity production costs were excessively high, ranging from > 65p/kWh at 11kWe output to 22p/kWh at 108kWe net output, as the micro-turbine and gas compressor typically comprised over 45-59% of the installed

costs. A similar engine system, at 50-250kg/h would have net electricity production costs of 15.5 –7.7 p/kWh for a similar engine based system at 50kg/h biomass input, 42kWe net output. All costs taking wood fuel cost of £25/t delivered to site. Compared to a biomass gasification + gas engine system, operating at electrical outputs in the top end of the range from 90-110kWe, the MGT system is 3-4 times more expensive.

CONCLUSIONS

- The catalyst modules have proven to be highly effective at oxidation of the producer gas fuel components within realistic producer gas-air mixtures over a range of pre-heat temperatures. The most resistant fraction to oxidation, the methane component, was 90% oxidised at pre-heat temperatures above approximately 200°C. This temperature is easily attainable in micro-turbine systems via heat exchangers transferring heat from combustion outlet stream to the input air-fuel stream.
- This gives an additional mechanism to utilise producer gas as a micro-turbine fuel should the direct fuelling of the micro-turbine combustion chamber prove untenable.
- The CO oxidation is extremely effective, with combustion outlet CO levels at least as low as those present in ambient air.
- The catalyst module was capable of oxidising the highest flow-rate of producer gas used in the tests (5.25kW). Further tests would be required to determine an upper limit to this performance.

- Experimental campaign curtailed due to gas compressor mechanical problems.
- MGT successfully operated on producer gas from clean wood feedstock, however, only 350 hours intermittent operation was obtained due to a common fault of the grid connection failure.
- Local grid problems meant that continuous operation was not possible.
- Emissions from the MGT were very comparable to that of the work carried out by Advantica.
- The techno-economics showed that the costs of electricity production from a gasification+micro-turbine system are very high – typically 22 p/kWh at 108kWe net electrical output.

POTENTIAL FOR FUTURE DEVELOPMENT

As there is virtually no economy of scale in using micro-turbines of 30kWe, there is very limited scope for development to a commercial system, unless Substantial reductions in capital costs of the turbines and reduction in the turbine deration are achieved. This may be possible if larger 250kWe turbines are used, as they offer higher efficiencies and a lower installed unit cost.

COMMUNITY COMBINED HEAT AND POWER: THE CEREDIGION BIOMASS INITIATIVE

British BioGen

OBJECTIVES

To develop an enabling methodology to allow local stakeholders:

- To become involved in biomass developments in their area at an early stage.
- To initiate projects.
- To assist developers in the design and execution of projects in a manner compatible with the commercial goals of the potential investor and local acceptance.
- Specifically the project aimed to set up and manage three working parties comprising all stakeholders to oversee development and undertake feasibility study to:
 - Assess current and future energy demand for the site.
 - Undertake full technical appraisal to define optimum technical solution and fuel supply requirement.
 - Undertake fuel supply study to determine optimum fuel supply strategy.
 - Investigate commercial options for investment and operation and develop a solution compatible with all stakeholder requirements including outside investors.
- Undertake full investment appraisal and prepare model company structures and contracts.
- Investigate environmental impacts, positive and negative, and consult with principal regulatory and statutory consultees.
- Develop and set-up a mechanism to enable the stakeholder to let/identify the power/heat sales contractor for the project.

SUMMARY

This study came about through a desire of a community leader, the then Member of Parliament for Ceredigion Cynog Dafis MP, to initiate some bio-energy developments in his constituency. British BioGen was asked to assist in the process and introduce some potential investors. This report is a narrative of the process of forming a local stakeholder group and its progression from initial engagement, through many trials and tribulations, in a collective attempt to realise a bio-energy CHP opportunity in the Aeron valley. The study and report is as much about stakeholder group process as it is about the particular opportunity identified.

COST

The total cost of this project was £115,180 with the Department of Trade and Industry (DTI) contributing £32,180, and British BioGen and industry stakeholders the balance.

DURATION

15 months – May 2000 to August 2001.

BACKGROUND

The study was conceived around a real bio-energy opportunity based on a dairy complex comprising a cheese factory, a milk drying plant and a logistics depot with cold storage. The site appeared to have the ideal profile for a biomass CHP project. The site was off the gas grid, it operated 24 hours a day 365 days a year and had a stable heat load. Furthermore the site was at the limits of its current electricity provision and owing to expansion plans the additional supply need would require grid reinforcement. A potential investor had been found in Shell Renewables and a local stakeholder group had agreed to assist the development.

The stakeholder group comprised a wide spectrum of community interests including the County Council represented by elected members and officials.

THE WORK PROGRAMME

The project was conceived to develop an enabling methodology to assist local stakeholders to participate in bio-energy market development in their area. The local stakeholders and the potential investors would work together to initiate, plan and execute

projects in a manner that would ensure the potential investors could achieve their goals, whilst also satisfying the needs of the local community. The programme of work extended over two years and comprised three phases:

Initiation and Stakeholder Recruitment

Following the initial contacts between the major promoter, Cynog Dafis MP and British BioGen, it was agreed to hold an initial meeting in Ceredigion to gauge interest and attempt to chart a path forward. The initiative immediately interested the County Council who agreed to assemble a wide range of local stakeholders. British BioGen agreed to recruit potential investors and provide the industry expertise. This wide stakeholder group met bi-monthly for over two years and became the major driving and coordination force for the project.

The group included Council elected members and officials, representatives of the farming and forest industries, environmental NGO's, local consultants and business interests, the potential investors and industry experts. The Welsh Development Agency played a pivotal role by providing meeting facilities and supporting developments through funding feasibility studies.

The early meetings dealt mainly with 'getting to know the subject' issues such as correcting current received wisdom about bio-energy, understanding Government policy and looking at the benefits and disadvantages of different kinds of bio-energy projects.

Opportunity Exploration

During this phase, a range of potential opportunities were suggested and discussed. The range of opportunities included:

- Heating systems for Council Buildings.
- Heating systems for homes and businesses.
- Integration with Current Council new build projects heat or CHP.
- Replacing existing Council heating boilers as they come up for replacement.
- Combined Heat and Power systems for local major energy users – eg The Aeron Valley project.
- All these options were discussed in detail and a structured approach for evaluation developed. This structured approach was built around a programme of feasibility studies which were undertaken by various stakeholder members. The core feasibility study looked at the technical and resource issues for the Aeon Valley project. The findings from this resource study was then used to inform resource issues pertaining to all the other opportunities.

Opportunity Evaluation

As each feasibility study was completed it was brought to the stakeholder group for discussion and evaluation. The findings of each study was reported by presentation at the group meetings and discussion and evaluation began.

This proved to be a revealing aspect of the study as it demonstrated the valuable contribution that the local stakeholders can provide. In particular it revealed the wider issues that need to be taken into account when developing projects such as public perceptions and key local issues.

It was unfortunate that the major investor withdrew from the project at this stage owing to a high level decision to refocus bio-energy developments outside the UK.

RESULTS AND CONCLUSIONS

Community Process

This project demonstrated that the harnessing of community interest gives local bio-energy market development drive and a rationale that all stakeholders welcomed. All stakeholders could identify with the project and feel 'ownership'. This was evidenced by the excellent attendance record of stakeholders at meetings and the 'halo' effect, which encouraged the local champions to undertake their own development activities outside the scope of the initial project.

The local stakeholders provided direct access for the developer to sources of information, advice on 'do's' and 'don'ts' and general guidance on the local political scene and how best to manage objections and deal with negative public reactions.

As the project evolved the local planning department began to become very pro-active in guiding and initiating new developments, attempting to integrate activities into development plans and provided excellent support.

The problems encountered included:

A general lack of awareness of biomass and bio-energy and the difficulties produced by negative perceptions emanating from previous planning applications.

A policy context which was national and general and difficult to translate to local needs and requirements. It was evident that the 'community' was more

interested in heat rather than electricity, had a huge desire to encourage development of all kinds yet lacked the legitimacy of a mechanism such as local targets.

Communication and Public Perception

The local public perception of bio-electricity plant is largely negative because of high perceived local impacts which are not balanced by a clear understanding of local benefits.

The general perception of biomass heat is positive because it is deemed to have low local impacts but substantial local benefits.

The negative perceptions have been informed largely by controversy (such as contentious planning applications) attenuated by the local press.

The study confirmed previous work on risk perception which highlights the importance of addressing the following risk attributes in any public communication, namely

- The fear of new technology.
- Who gets the benefits (balance local with national).
- Accident potential.
- Impact on children's health (largely emissions and traffic).

The local stakeholders were shown to be the most credible communicators, followed by recognised non-partisan authorities such as environmental NGO's. Government and developers fall far behind in credibility and ability to persuade.

The most effective communication medium is 'demonstration' such as a visit to a real plant and interaction with other local community representatives. The lack of suitable communication tools to address the key risk

attributes proved to be an initial difficulty.

The Council demonstrated a **significant opportunity in its existing estate for biomass heating** and was eager to pursue at least 10 of the sites identified. However, lack of an existing supply structure and purchasing rules which favour low capital costs over low whole life costs made realising these opportunities slow and difficult.

The study has confirmed that **substantial biomass resources** exist within a 40-mile radius of the proposed plant. There are therefore adequate existing resources to serve the plant but a prudent supply strategy would also include the development of energy crops up to about 1000Ha.

The study shows that current economics are marginal without grant. Bioenergy is an emerging industry with few current deployment economies. The returns to farmers from energy crops are no better than upland sheep without grant and just about respectable with grants at levels currently seen in England.

This project could be a focus for energy crop development in Wales.

The market opportunity is a good model comprising industrial CHP with heat and electricity profiles very close to the ideal. The scale is appropriate to the area and a number of energy crop models could be explored to test yield performance and acceptability and fit to local agriculture.

The implementation of this project should pursue the central fuel processing plant model for two major reasons. Firstly there is a customer requirement to isolate the fuel processing plant from the food processing plant for bio-security and other practical reasons. (lorry movements, image of cleanliness etc)

and secondly because it enables the development of secondary markets such as heating schemes.

The study also provided an understanding of the customer needs profile which an embedded CHP project of this kind would have to satisfy. Of primary importance is reliable plant with possible back-up. Company reputation was also seen to be key issue to provide reassurance about reliability and safety.

New developments and Council new build proved to be a fruitful area and a number of projects are in gestation. This is an area where the stakeholder group could exercise real influence and ensure that biomass was considered from the outset. Decisions taken in the group were taken to Council meetings where these new projects were planned and developed. This ensured that more radical solutions could be investigated such as biomass district heating for a housing estate or a biomass CHP system for a light industrial development. Furthermore the facilities contractors involved in building these new developments could offer long term heat contracts thereby providing sufficient security to underwrite investment in supply chain development.

The sample survey showed that **biomass heating for homes and businesses** had a wide attraction based largely on the appeal of a locally produced fuel. Realistically however, the stakeholder postponed further promotion of this opportunity until larger projects had stimulated the creation of a local supply chain.

RECOMMENDATIONS

Local targets give context and legitimacy to community promoters and the absence of targets inhibit action. Policy goals should be expressed in terms of local targets whenever possible.

Targets and Government policy needs to be better communicated to local actors.

Any developer contemplating a significant bio-energy development would be prudent to begin with the premise that **initial perceptions will be negative** and that local media feed on controversy and can attenuate these early day negative perceptions very effectively. Communication strategies must be well thought through and must address the risk issues previously identified in this report.

This study vividly demonstrated the power of a **community group as a vital communication channel** to promote the project. Local stakeholders are credible and persuasive communicators because they have authority and respect. The developer will always start on the back foot and is best advised to channel communication through this important medium.

All bioenergy developments have **negative local impacts** and it is vital that projects should be presented in a way that highlights the local benefits in a credible way to counteract the perceived dis-advantages. Promoters publicity material would be advised to adopt a local to general approach with the initial copy focussing singularly on local benefits and concerns.

Whilst demonstration is the most effective persuader further **work is required to develop** the data tools to quantify and address the key risk attributes. The study demonstrated how reasoned argument supported by appropriate studies and data could be persuasive if it addressed issues of local concern.

The key risk attributes that need to be addressed are the **fear of new technology, who gets the benefits** (balance local with national), **accident potential impact on children's health** (largely emissions and traffic).

BIOMASS-FUELLED INDIRECT-FIRED MICRO TURBINE

Talbott's Heating Limited (with Bowman Power Systems)

OBJECTIVES

- To further develop micro turbine indirect firing and to develop this into a biomass generator, building on the success of the previous project (report ref. URN 02/1346).
- Specific aims were:
- to achieve 4000 hours run time
- to establish a start procedure
- to develop safe and predictable operation without the need for supervision
- to prove the heat exchanger concept
- to achieve full recuperated operation
- to achieve high temperature combustion with low emissions
- to establish costs and technical basis for future development
- to provide a demonstration of working biomass renewable power generation.

SUMMARY

This project aimed to build on the success of the previous project by further developing and improving the system.

The system was redesigned and rebuilt using the experience gained and the recommendations reported in the previous project. The efficiency, maintenance and safety of the system was improved through this development project.

COST

The total cost of this project was £357,860 with the Department of Trade and Industry (DTI) contributing £178,930, and Talbott's Heating Ltd and Bowman Power Systems the balance.

DURATION

22 months – September 2002 to July 2004

BACKGROUND

Talbott's Heating, working with Bowman Power, has developed, with the support of the DTI, a biomass indirect-fired air turbine system. The system was based on the Bowman TG50 50kW_e turbine and a C3(S) combustor with a high temperature heat exchanger. The system is fired on biomass to provide electricity in a very efficient and simple manner. The 'Biomass Combustion Gas turbine

CHP' project has provided the proof of principle.

Biomass combustion represents a carbon dioxide neutral, renewable energy source and produces less carbon monoxide and particulate matter than an average gas boiler, without the sulphur emissions associated with fossil fuels.

Converting biomass heat energy into electrical energy is currently limited. The traditional method involves producing steam by passing the hot biomass combustion gases through a waste heat steam boiler. This steam is then used to drive a steam engine or turbine generator. Steam-based systems provide low fuel-to-electrical output efficiencies owing to the dumping of heat in the condensation phase. As a result fuel feed rates are high and the electric outputs are low.

Small-scale steam-based generation using biomass combustion is very expensive owing to the steam raising and dissipation equipment needed; this leads to unacceptable payback periods. The economics of steam are hard to justify under 1MW because of low efficiencies and high capital costs. Steam is easier to justify when there is a use for the excess heat (CHP), but this relies on a constant demand for heat when the system is generating.

There is a large demand for a simple, highly efficient biomass generator under 1MW. Energy crops schemes that are being pushed currently require an efficient energy end use. The more efficient the biomass-to-electrical energy system is, the easier it will be to justify and promote energy crops. The smaller size system provides benefits in that fuel transportation costs can be reduced. An added benefit is that power can be provided where it is needed, reducing the strain,

cost and power losses in cabling to remote locations.

THE WORK PROGRAMME

A short report was commissioned to outline the specification of commercially available high temperature heat exchanger materials and to determine their suitability for indirect firing. This report confirmed the material selection and also provided material alternatives.

A new, larger, biomass combustor was manufactured at Talbott's factory in Stafford. The high temperature heat exchanger was extended with a new outer case designed, manufactured and fitted to the biomass combustor. A series of tests was conducted to evaluate the thermal performance characteristics of the biomass combustor and heat exchanger using the existing turbine generator from the previous project.

The PC-based mathematical model of the system was adapted to take into account the physical characteristics of the system. Bowman Power and Talbott's worked together to re-commission the TG50 turbine to incorporate the new biomass combustion system. Modifications were made to the pipe work to reduce pressure losses along with extensive starting control software changes. Start-up and shutdown procedures were developed and tested with over 100 successful starts.

Full recuperation of waste heat from the turbine exhaust is possible via modified ductwork and it is returned into the combustion air stream whilst maintaining combustion control; this provides a reduction in fuel consumption and improved emissions. Extensive modifications to combustor

internals were made to cope with the high volume flow rates and temperatures without causing combustion problems. The biomass generation system was tested for over 4000 hours and data captured in real time via PC-based ModBus and other data logging packages. Generated power from the Biomass Combustion Turbine during the testing ranged between 20 and 30kW.

Although the system is still developing, and could benefit from an increase in both combustor and heat exchanger size, capital equipment costs for this 30kW_e prototype are around £2500 per kW_e. Comparing this with Talbott's current steam-based 50kW_e CHP system with an electrical efficiency of 8% and cost of £6455 per kW_e, this represents a great leap forward at this size.

Commercial prospects for this technology are good with over 3500 existing worldwide installations of the heat-only systems. It is predicted that a large number of previous customers will be interested in producing electricity from their existing waste fuel supplies. The 30kW_e unit could provide an offset to a normal base load of 250kW_e average in woodworking factories. With electricity being purchased at 5p/kW this would save £1.50 per hour; operating this unit for 8000 hours per year will save £12,000; ROCs (Renewables Obligation Certificates) will add another 3p/kW (although sale on the open market may yield 5p/kW), this will add a further £7200. Therefore, the payback period can be calculated to four years. Heat output will make the system more attractive as well, by cutting gas or oil costs. Larger units with higher efficiencies and lower costs per kW will, of course, provide much faster pay back; a 250kW_e system is expected

to have a payback period of just 2 ½ years.



Figure 1 Views of the test set-up

RESULTS

The starting procedure has been developed and is now well proven, with over 100 successful starts. The system has run for over 4000 hours, producing between 20 and 30kW in a very stable and reliable manner.

Heat exchanger performance has been benchmarked and durability has been proved. Materials for the heat exchanger have been studied and results obtained from actual running. A sample of heat exchanger tubing that was subjected to combustion temperatures ranging between 900 and 1150°C was submitted for testing after 4000 hours operation in order to evaluate the depth of oxidation into the underlying steel. A polished section was prepared perpendicularly through the sample and examined using optical light microscopy. The normal oxidation thickness of the piece is in the range of 5-20µm thick and has formed as a continuous dense oxide layer. Occasional masses of up to 130µm thick are formed at grain boundaries within the steel surface.

All of the waste gases from the turbine are re-used in the combustion chamber, giving 100% recuperation. System performance has been evaluated and benchmarked for further development.

Measured performance:

Combustion temperature testing range	900-1150°C
Turbine entry temperature testing range	700-850°C
Net electrical output testing range	18-35kW
Heat exchanger efficiency	71%
Exhaust gas temperature	300-330°C (for CHP)
Compressor isentropic efficiency	62%
Turbine isentropic efficiency	80%
Overall efficiency	15%

Measured emissions:

CO	0.001 to 0.01 vol %
CO ₂	7.4 to 7.5 vol %
NO _x	2-10 ppm
Particulate emissions	50 mg/m ³

Commercial and marketing research indicates a 100kW_e size would be the minimum size to be currently justifiable. The initial cost of a 100kW_e biomass generator would be around £250,000. With flow line production the price is expected to drop to around £200,000 for each unit. Producing 100kW_e in one year, it will produce 800,000kWh of electricity. The electricity can be sold for 2p/kWh, which in one year will total £16,000. For each kWh, 5p can be received for the electricity producers' ROCs; this will amount to £40,000/yr. Therefore the overall amount received for the electrical output will be around £56,000/yr.

Significant levels of carbon emission savings can be made through the use of this unit. Carbon emission savings made through the use of a Biomass Generator with an electrical output of around 100kW and a thermal output of around 150kW compared with traditional fossil fuel-fired systems are

calculated below. Average CO₂ emissions from UK fossil fuel generators, including transmission losses are estimated at 183g/kWh, therefore:

$$100\text{kW} \times 8000\text{hrs} \times 183\text{g} = 146.4\text{t/yr}$$

Average emissions from UK fossil fuel boilers are estimated at 98g/kWh, therefore:

$$150\text{kW} \times 8000\text{hrs} \times 98\text{g} = 117.6\text{t/yr}$$

Hence, the total CO₂ emission reduction per year for each unit will be 264 tonnes.

CONCLUSIONS

The main achievements of these projects are:

- Start procedure established and well proven with over 100 successful starts.
- 4680 hours of turbine operation so far.
- Safe and predictable operation without supervision.
- Heat exchanger concept proved.
- Fully recuperated operation achieved.
- High temperature combustion achieved with ultra low emissions.
- The Biomass Generator has demonstrated that it is possible to produce 20-30kW of renewable electricity in a stable, reliable manner.
- Cost and technical basis for future development established.
- Demonstration of working biomass renewable power generation.

As the concept is now well proven the next logical step is to improve the system and build on its success.



Figure 2 View of combustor from feed side

POTENTIAL FOR FUTURE DEVELOPMENT

- To manufacture a new 100kW_e system.
- To improve the overall cycle efficiency.
- To re-design the biomass combustor to incorporate the higher air return temperatures and volume flow rates; other improvements could be incorporated in line with the experience of this system.
- To utilise waste heat from the system in heating and cooling applications; thus making an efficient biomass-fired Co-gen and Trigen system.

SECTION 6

BIOMASS HEATING

PROJECT SUMMARY LISTING

Report ref or URN	Title	Contractor	Publication date	Page no.
00/1468	Top Outfeeder System and Burner Head for Wood as Fuel	Nordistribution Limited	January 2000	223
B/U1/00617/REP	Biomass Heating at East Surrey Hospital: Technical Evaluation	Surrey and Sussex Healthcare Trust	January 2000	226
B/U1/00632/REP	Establishing Biomass Heating in the UK: Phase II	British BioGen	July 2000	231
B/U1/00647/REP	Shenstone Lodge Heating Demonstration Project: Phase II	Talbotts Heating Limited	August 2000	235
01/546	Monitoring Wood Heating Plants	CRE Group Limited	January 2001	239
01/1006	Development of Cordwood Boiler System	Nordistribution Limited	July 2001	243
01/1014	Introducing Wood Pellet Fuel to the UK	Renewable Heat and Power Limited	August 2001	246
02/964	Cartridge Furnaces for the Biomass Industry	ESD Limited	January 2002	251
02/1439	Investigation into the Practibility of Burning Biomass on Underfeed Stokers	Ashwell Engineering Service Limited	July 2002	255
02/1343	Development of Stoker-Burner Wood Chip Combustion Systems for the UK Market	Econergy Limited	November 2002	259
02/1348	Technical Development of Retrofit Wood Burner for Coal Under-Fed Stokers in County Durham North Energy Associates and Set Up of Demonstration Facility	Durham North Energy Associates	November 2002	263

TOP OUTFEEDER SYSTEM AND BURNER HEAD FOR WOOD AS FUEL

Nordistribution Limited

OBJECTIVES

- To investigate the option of a top outfeed system for the storage of woodchip fuel, with the aim of reducing the capital cost of traditional systems.

SUMMARY

This report is the culmination of an investigation into enhanced wood fuel handling and market design studies. From the report the perceived barriers for the utilisation of woodchip were the capital cost for the classical solution for woodchip fuel storage and outfeed, this being a concrete bunker and push rod system. The cost for the mechanical engineering of this equipment was often far outstripped by the cost of the building and civils implications.

The report highlighted three woodchip storage and handling systems that would assist in overcoming the difficulties of integrated fuel delivery, storage, handling and the commercial considerations mentioned above.

The first option chose equipment that was for the roll-on/ roll-off bin delivery system, which has now completed trials and has been installed in a number of the first biomass chipped wood projects in the UK.

The second option was for a simple above ground silo, with an improved flat bottom outfeeder, as used in other European countries. This has been utilised on a local project where chip can be blown into the above ground silo. This is at present under operational tests.

The third option was for a top outfeed system, and this is the report from the development of this project. A previous report listed a number of items that were considered to be of importance to assist with the utilisation of biomass. These included reduced costs towards commercial price, no civils, delivery vehicle access, and package designed and adaptability.

The top outfeed system meets all these requirements. The system is basically designed for a conveyor to be lowered onto a pile of chips and discharging to one end with a simple standard cross screw, feeding into the transport screw of the boiler.

COST

The total cost of this project was £87,600 with the Department of Trade and Industry (DTI) contributing £25,000 and Nordistribution Limited the balance.

DURATION

20 months – May 1998 – December 1999

BACKGROUND

Biomass, and in particular wood chip, is gaining acceptance in the UK for the generation of energy, to assist with the global demand for renewable energy sources.

Wood chips do not flow and the regular and controlled supply of wood chip is essential for correct combustion of the product and energy production.

Below ground bunkers, with hydraulic scraper floors, were seen to be the classic solution with fuel delivered by tipper, trailer or truck. This solution however, has some shortcomings – these include the capital cost for the civil engineering implications, often doubling the cost of installations and the difficulty of retrofit for this type of plant.

A new system, the top outfeed system was investigated in this report. The perceived advantages of this system were for retrofit with low capital cost and simplicity of operation enabling delivery from a tipper vehicle.

The second part of the project was to obtain the technology for a simple biomass/ woodchip burner head.

THE WORK PROGRAMME

The aim of the project was to carry out trials on the top outfeed system. The test site chosen was 'The Heart of The Forest Project' in North West Lancashire. The installation of equipment on that site would enable the project to proceed by working with an organisation that has a strong

affinity with the aims of the industry for the utilisation of biomass.

Initial meetings were held with the head of the Forest Management Team and the location of the boiler was agreed. The boiler was to be located adjacent to the existing gas boiler and low pressure hot water pipe work would be immediately adjacent to that with the existing capped connections. The outfeeder would also be located within the building giving the opportunity to prove the operation of the plant within the present building. The boiler size was as given by a consultant engineer's report, which also indicated the approved and accepted supplies of wood fuel that were available within the geographic area.

The system was then fully designed, manufactured and tested at the site.

RESULTS AND CONCLUSIONS

Top Outfeeder

- The opportunity for cost reduction can be achieved with the reduced civil engineering implications, the retrofit opportunity into existing premises and with volume manufacture. It is believed the cost could be within original budgets of £8,194 with multiple manufacture. The enclosure costs, however, would be in excess of the assumed target of £15,000. The enclosure system meets the technical requirements and is believed to be commercially viable.
- The flat based outfeed compatibility level is good
- The outfeed is along the full length of the system although the

issue of height of storage could be investigated further.

- The reduced civil engineering implication in respect of this equipment is a major advantage. The only civil engineering implications are the excavation of the metering bin for level and feed control, and that the system requires a level concrete base for both the outfeeder to operate and for the mechanical fixings for the enclosure.
- Delivery vehicle access is good with the possible exception of limits to the vehicle height if installed within an existing building.
- The package design for the equipment could be delivered and this would integrate with the opportunity for volume production.
- Adaptability for the unit is definitely possible with varying physical sizes and output suiting installation in existing premises.
- The size of boiler for which the outfeeder is best suited is 50-500kW. The equipment is simple in operation, robust in design and appears to operate on a continuous basis with good quality fuel.
- Burner Head
- It was proven that the burner head is particularly suitable for the residential/ commercial sector of the market with the smaller boiler installations and good quality fuel supply.
- Could be used as a retrofit to an existing boiler.

POTENTIAL FOR FUTURE DEVELOPMENT

Top Outfeeder

- Consideration as to export potential to enable assembly of volume manufacture opportunity.
- Electrification of hoist.
- Improvement to overall appearance.
- Relocation of cross screw adjacent to outfeeder to enable an increase in storage volume.
- Investigation of packaged/ weathered storage container for external use.
- Burner Head
- Reduction of footprint size to enable use in similar existing and new boiler houses.
- Modify to enable simply bolt-on option for existing equipment.
- Revised agitator retort screw to enable best distribution of material.

General

The equipment as described above will play a role in the utilisation of biomass throughout Europe as is confirmed by the interest in all countries in respect of this equipment. The success in this race will be in volume manufacture of the product. The need therefore, is to develop the equipment that is designed for multiple manufacture incorporating the relevant technologies.

BIOMASS HEATING AT EAST SURREY HOSPITAL: TECHNICAL EVALUATION

Surrey and Sussex Healthcare Trust (with LRZ Energy & Environment)

OBJECTIVES

- To assess and report on existing services provision for heating and cooling.
- To assess and report on technical aspects of the proposed biomass scheme.
- To assess and report on commercial aspects of the proposed biomass scheme.

SUMMARY

East Surrey Hospital (ESH), managed and operated by the Surrey and Sussex Healthcare Trust, has a large and diverse energy requirement that offers the potential to develop a 'model' biomass-heating scheme. Such a scheme has been proposed by Connick Tree Care (CTC), a local arboricultural company that produces large quantities of woody arisings from its tree work. CTC has offered to provide such a scheme as an 'Energy Services' package under which it would finance and operate a biomass installation, selling energy to the hospital at agreed tariffs.

This report provides the results of a detailed evaluation of the proposed biomass heating installation at East Surrey Hospital. It is intended to allow the Trust to make a decision on

whether to proceed further with the scheme and, if so, on what basis.

COST

The total cost of the project, £5,653, was met by the Department of Trade and Industry (DTI).

DURATION

Seven months - July 1999 to January 2000

BACKGROUND

ESH is a Nucleus Hospital. One of the features of ESH and other Nucleus Hospitals is a centralised services installation. At ESH, this includes:

- Boiler plant (steam and LPHW)
- Domestic hot water heaters
- Chiller plant (for air conditioning)
- Ancillary heating services (pumps, controls, etc.).

These service the primary energy needs of the hospital, and in 1997 total energy consumption was approximately 13.4 million kWh of gas and 1.2 million kWh of electricity.

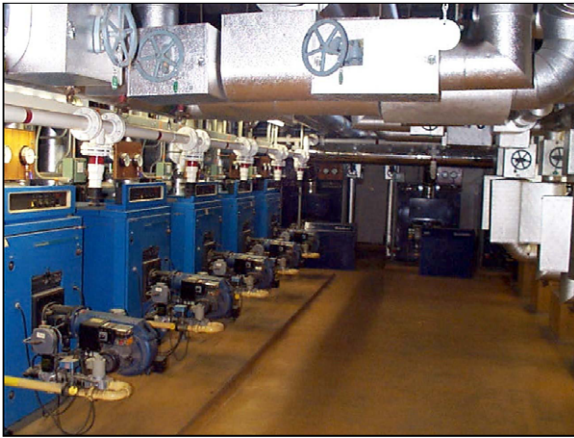


Figure 1. View of bank of LPHW gas boilers

This represents a substantial and relatively diversified energy demand, and makes ESH a potentially ideal site for the installation of biomass boiler plant. The reason for this is that, although the plant itself is relatively capital intensive (so that the installed costs tend to be significantly higher than for conventional oil or gas boilers), fuel input costs can be significantly lower. This can make biomass boiler plant very cost-effective if it can be used to meet large-scale and continuous or near-continuous energy demands, since these can generate substantial fuel cost savings to offset and effectively 'pay back' the additional capital costs. The imposition of the Climate Change Levy (CCL) will significantly increase the cost-effectiveness of biomass heating by increasing the cost differential between wood-fuel, which is exempt from the CCL, and both gas and electricity.

However, any such proposal is predicated on the availability of a reliable source of wood-fuel at a competitive cost. Thus, the underpinning of the proposed scheme at ESH is the involvement of British BioGen member Connick Tree Care (CTC). CTC is a locally based arboricultural company, with its main yard at New Pond Farm, Woodhatch

Road, Reigate, approximately one mile from the hospital. It currently ranks amongst the largest arboricultural companies in the UK, with approximately 22 tree gangs engaged in urban forestry and related tree management work, mainly in and around the Greater London area.

As an inevitable by-product of its tree work, CTC produces large volumes of woody arisings (estimated to be in excess of 5,000 tonnes per annum) consistently throughout the year. This material generally has to be removed from the work sites by the tree gangs, and its disposal becomes the responsibility of CTC. Currently, a large proportion is chipped as a means of volume reduction and brought back to the CTC yard at New Pond Farm.

These arisings represent a significant disposal issue, and CTC has identified use for energy production as an important and positive opportunity in this regard. Thus, it is currently planning to invest in the infrastructure necessary to process the material into a high quality woodfuel. This will primarily entail:

- Chipping of unchipped material
- Screening and re-chipping to control particle size and remove gross contamination
- Drying to a consistent moisture content (<35% wet basis)
- Storage.

This material is potentially available as a competitive fuel to ESH. However, the initial capital costs associated with installation of the boiler plant are significant and *even where it is potentially cost effective* can cause financing problems, particularly for public sector organisations, such as ESH, with limited capital budgets.

The lack of an established market for woodfuel and of regulated woodfuel standards means that potential purchasers place themselves in an exposed position if they become reliant on a single source of woodfuel.

Thus, rather than simply selling fuel, CTC are proposing to develop a complete package, along the lines of 'Energy Services' provisions, including undertaking the following:

- Finance and installation of a one megawatt (1MW) wood boiler on ESH premises capable of providing the hospital with its base load energy demands
- Supply of woodfuel to the boiler
- Boiler operation and maintenance (although routine daily attendance might be contracted back to ESH services staff - estimated at 15-20 minutes per day)
- Sale of metered heat to ESH at a delivered energy price competitive with current energy costs.

THE WORK PROGRAMME

The report has been undertaken using information provided both by ESH and CTC. Work included:

- An evaluation of the current energy services provision at ESH in the context of the proposed biomass boiler installation, looking at the configuration of the existing plant and any operational aspects.
- An assessment of the proposed biomass scheme (a c.1MW boiler to be run on woodchip fuel and used to supply the hospital's base load energy demands for LPHW,

DHW and potentially cooling as well).

- An assessment of both the technical and commercial aspects of such a scheme.

RESULTS AND CONCLUSIONS

- East Surrey Hospital has a centralised services installation, which represents a substantial and diversified load. This offers an opportunity for a cost-effective biomass scheme since, while capital costs are relatively high, this is offset by lower fuel costs, thereby generating a 'payback'. Current energy costs relating to energy services are c.£125k on gas and c.£60k on electricity.
- CTC has proposed providing biomass boiler capacity to ESH on the basis of 'Energy Services' provision.
- The existing services installation is complex and not well documented. This has made assessment difficult, but overall it is clear that there are large demands for space heating, DHW and chilling. These represent a year-round and large-scale energy requirement. The assessment of the existing infrastructure also indicates the following:
 - o There appears to be significant scope for rationalisation of the existing plant and control strategy, particularly as regards the steam plant. Demand for steam per se is relatively limited. Although the steam boilers are used to provide LPHW for space heating via a calorifier, they stand idling for long periods, generating high standing

losses. There appears to be scope to replace this plant with a much smaller steam boiler to provide for the limited steam requirements and a biomass boiler for space heating.

- o The original chiller units are close to the end of their life and are already experiencing very high maintenance costs. This offers the possibility of replacing them with absorption chillers driven by a MPHW biomass boiler.
- There are a number of options for a biomass scheme, all of which are technically feasible, but would need effective integration into the existing services. The main issues effecting which option is preferred are commercial ones.

Option	Heating capacity	DHW capacity	Chiller capacity	Chiller heat load	Minimum boiler load ¹³	Boiler size	System type
1	1000kW	150kW	266kW	457kW	924kW	1000kW	MPHW
2	1000kW	150kW	350kW	547kW	994kW	1000kW	MPHW
3	1000kW	150kW	0	0	447kW	1000kW	LPHW
4	750kW	150kW	0	0	447kW	750kW	LPHW

Table 1. The possible scheme configurations

- All aspects related to the core installation and operation of a biomass boiler would be financed by CTC and paid for by tariffs that are competitive with conventional delivered energy costs.
- A number of capital costs (including steam plant rationalisation, LPHW back-up provision, chiller units and modification to the control system) would be wholly or partially excluded from the core tariff structure being proposed by CTC. Some apportionment of these costs to the hospital is believed to be reasonable, but it is

clearly essential that these are identified and apportioned appropriately in a detailed proposal from CTC.

- As well as costs, there are a number of other elements that must be considered in assessing the CTC proposals and, ultimately, must be reflected in a contract. These include:
 - o Tariff variation during the contract
 - o Contract length, reviews, break points and re-negotiation
 - o Use of space on the ESH site and access issues
 - o Procurement of insurances and consents by CTC
 - o Use of ESH staff, including training, management and reporting, and health and safety
 - o Penalties.

The concept being proposed is potentially a strong one, and would produce a number of both financial and non-financial benefits to the hospital. Importantly, it could also provide the catalyst for rationalisation of the existing services provision that could produce immediate and substantial savings in running costs quite apart from any savings directly related to a biomass installation.

POTENTIAL FOR FUTURE DEVELOPMENT

Clearly, fully detailed proposals are now required from CTC covering all of the above, and these should be given serious consideration. Ultimately, however, any decision on whether or not to proceed will depend upon a few key aspects:

- The robustness of the proposed scheme, both technically and commercially
- The capital costs that the hospital is asked to bear, primarily associated with rationalisation of existing services and with new chillers
- The competitiveness of the tariff structure that is proposed by CTC.

ESTABLISHING BIOMASS HEATING IN THE UK: PHASE II

British BioGen

OBJECTIVES

- To accelerate the rate of deployment of biomass heating in the UK.
- To enable and encourage greater co-operation and innovation within the UK biomass heating industry.

SUMMARY

In 1996, British BioGen took on the Biomass Heat Working Group, which was first set up in 1995. During the summer of 1996, British BioGen, supported by the Department of Trade and Industry (DTI), worked with the group to produce A Strategy to Develop the UK Market for biomass heating installations. In the spring of 1997 British BioGen agreed a two-year programme with the DTI to establish biomass heating in the UK. The programme aimed to bring together industry stakeholders and assist in the development of a significant biomass heat market in the UK.

The project has been successful in its aim to increase the volume of biomass heating enquiries and enable greater use of the industry knowledge base. Throughout the duration of the project a number of new biomass heating systems have been installed, including Shenstone Lodge School, Boughton

Pumping Station and Elvendon Priory. In addition, an efficient system of information exchange has been established for customers and industry. British BioGen believe that the benefits of this system will be a crucial factor in achieving bioenergy industry targets of 2MWt for domestic heating, 2MWt for industrial and commercial heating and 2MWt for CHP by the end of 2001.

COST

The total cost of this project was £200,385, with the Department of Trade and Industry (DTI) contributing £70,635 and UK industry the balance.

DURATION

13 months – June 1999 to July 2000

BACKGROUND

It is widely accepted that bioenergy has the potential to play a major role in renewables policy and rural regeneration and that it presents a major new opportunity for the UK manufacturing sector.

The bioenergy heat market is growing fast, and the impact of the climate change levy is likely to have a significant impact, particularly on industrial heat markets. This market

has the capability to become one of the most important markets for bioenergy. Heat is the most important single energy market in the UK and the European Union; the heat market amounts to 45% of the total UK energy market. Wood as a fuel for heating homes and industry amounts to 30% of the UK's renewable energy use. For industries faced with an increasing environmental tax burden, the ability to access a renewable fuel that is compatible with their existing heating systems will become increasingly attractive.

In June 1999, the total number of wood heating installations recorded was 18, comprising of domestic, commercial/industrial and CHP, which amounts to 3.4MWt installed capacity.

THE WORK PROGRAMME

The work for this project was split into two distinct phases. The first phase aimed to increasing the volume of realistic biomass heating enquiries reaching suppliers and reducing the unit cost to suppliers of servicing those enquiries. This was achieved by:

- Reviewing target markets and methods.
- Producing a market development plan for 1999/2000.
- Updating enquiries service/ staff training.
- Setting up a telephone enquiry/ advisory service.
- Producing marketing materials and commissioning a biomass heating display.
- Creating a website for biomass heating.
- Developing a biomass heating PR system.

- Holding PR events on biomass heating throughout the country.
- The second phase of the project aimed to increase and enhance the knowledge base on biomass heating. This was achieved by:
- Developing the knowledge base structure, content and rules.
- Ensuring that the knowledge base was maintained and updated.
- Developing and administering an industry information exchange.
- Updating structure and administration and attending working group meetings.
- Further developing and promoting good practice.
- Designing a future biomass heating advisory service.
- Contributing to knowledge acquisition through the commissioning of a variety of reports.

CONCLUSIONS

Review of target markets and methods:

Differences in the number and type of enquiries received during this phase of the programme, compared with the first phase, were highlighted. This included a reduction in enquiries on cessation of the Heating Advisory Service funding, which provided 50% funding of wood heating feasibility studies.

Market development plan for 1999/2000:

This activity assisted the HeatNet group in focusing on specific target markets and the activities necessary to promote biomass heating within these markets. It has also been used as the

basis for developing an Industry Biomass Heat Strategy for the UK. During the analysis it became apparent that there is a lack of information on the origin of enquiries.

Telephone enquiry/ advisory service:

Since the introduction of the web site customer information and enquiry service, the frequency of enquiries, in particular domestic enquiries, has risen. The web site provides an additional method of ensuring efficient forwarding of enquiries to industry.

Commissioning of biomass heating display:

The biomass heating display has a visual impact that should attract attention at exhibitions, conferences and seminars. It also contains information that will give the visitor an easy to understand explanation of the applications of wood heating. The stand is portable and easy to erect, which will make it suitable for taking to most events.

Maintenance of the knowledge base:

The maintenance of the knowledge base ensures that both customers and industry has easy access to the information obtained through this project, assisted by the use of the British BioGen website.

Development and administration of industry information exchange:

Using a variety of methods to obtain, provide and exchange information provides industry with opportunities to co-operate and share knowledge. Website and e-mail information exchange facilities have been set up.

Updating of structure and administration and attendance at working group meetings:

Six sessions of the HeatNet were held throughout the duration of the project,

which proved successful in encouraging greater communication and the exchanging of knowledge and experiences. These meetings assist in finding solutions to problems and sharing useful contacts.

Further development and promotion of good practice for equipment, fuel and service providers:

Further research is required into the development of industry standards, ownership and legal issues, etc. However, in order to assist the development of a code of good practice system further, British BioGen are entering into discussions with HETAS and CRE regarding certification of appliances and the development of biomass heating standards. Resources under the current project have been used for initial meetings and research to obtain information required to begin preparing codes of good practice. The Wood Heating Equipment Guide will incorporate the codes of good practice as they develop. This is an on-going activity that will require further funding.

POTENTIAL FOR FUTURE DEVELOPMENT

Review of target markets and methods:

Develop and promote the heating advisory service to ensure it is available to target markets.

Use the market development plan to ensure focussed deployment of biomass heating.

Market development plan for 1999/2000:

Ensure that the Industry Biomass Heat Strategy is easily accessible to HeatNet members. The strategy will be used by industry to maintain a co-ordinated

approach to the development of this market sector.

Include a section in the wood heating questionnaire that will identify the origin of the enquiry.

Telephone enquiry/ advisory service

Develop the website enquiry service and information section:

Altener II funding to continue the 50% funding of wood heat feasibility studies has been secured. Ensure that this is publicised through the National Energy Foundation, energy agencies and consultants who receive regional wood heating enquiries.

Commission Biomass Heating Display:

Ensure that the information on the stand is updated as necessary. Display stands can go out of date relatively quickly, especially in a rapidly developing industry like bioenergy.

To ensure the stand is used to its full potential, a plan of exhibitions that will reach the identified target audiences should be compiled. This will help maintain a higher profile for biomass heating, and therefore generate more enquiries for industry. Events such as Nemex, which are largely focused on fossil fuel technologies should be attended to raise the profile of biomass as an alternative to fossil fuel technologies.

Continued maintenance/ updating of the knowledge base:

Pass on the information to industry when new or updated reports are available.

Ensure that all reports are available on the website, so that both customers and industry continue to have easy access to new and updated information.

Development and administration of industry information exchange:

Continue to promote regularly to HeatNet the availability of the e-mail and website exchange service. This can be done by British BioGen posting enquiries on the system to encourage responses.

Update structure and administration and attendance at working group meetings:

Continue to hold six meetings per year of the HeatNet, in order to maintain effective communication and exchange of experiences within industry.

Further develop and promote good practice for equipment, fuel and service providers:

Develop and administer a certification scheme, based on industry codes of good practice.

Develop a set of codes of good practice as defined by the research currently being undertaken, and recommendations from the HeatNet.

British BioGen to develop the Wood Heating Guide into an approved list of suppliers.

SHENSTONE LODGE HEATING DEMONSTRATION PROJECT: PHASE II

Talbott's Heating Limited (with Forest of Mercia Partnership)

OBJECTIVES

- To continue the development and demonstration of new automated wood fuel handling technologies of the heating system set up at Shenstone Lodge School (in Phase I)
- To examine the feasibility of using standardised fuel pellets.

SUMMARY

This phase of work is designed to continue the work that was instigated in March 1997 with the installation of a wood combustion system at the Shenstone Lodge School. A key constraint was the problem of a consistent fuel supply. Phase II has been based on the use of a standardised manufactured wood pellet rather than wood chips produced from forest residues. The advantage of the pellet is that it has consistent characteristics in terms of size and moisture content, which will avoid the problems that had been experienced when using wood chip.

To enable the combustion system to use the wood pellets, the automated feed system has been modified. These modifications have enabled the combustion system to work continuously and the problems of fuel blockage experienced in Phase I have

not been encountered. The modifications have, however, meant a reduction in hopper size, which has required more frequent deliveries of fuel. This reduction has had no adverse impact on the demonstration, but clearly any future use of the combustion system would have to address this problem; otherwise, high delivery costs will make the fuel uncompetitive. The problems of fuel delivery were overcome by bagging the pellets at the production plant and then using a hi-ab to deliver the pellets directly into the hopper.

The level of emissions are low and well within acceptable levels. This is, however, a stand-alone demonstration, which has been reflected in the cost of the pellets. At present they are being supplied at £60 per tonne, which makes the fuel uncompetitive in comparison to gas. However, with an increase in use of the pellets to secure economies of scale and the opportunity to establish a local production plant, it is not unreasonable to expect the cost of the pellets to be reduced. To be competitive with gas, the delivered cost of the wood pellets should be around £40 per tonne. This second phase of the demonstration has however clearly shown that the pellets have the right characteristics in terms of size and moisture content. On average the moisture content was

shown to be 12%, but there is room to further reduce the moisture content by using covered vehicles for delivery.

COST

The total cost of this project was £12,000, with the Department of Trade and Industry (DTI) contributing £6,000 and Talbott's Heating Ltd and Forest of Mercia the balance.

DURATION

7 months - December 1999 to June 2000

BACKGROUND

This project is part of the on-going programme of research and development that is being co-ordinated by the Forest of Mercia Partnership to explore the potential of using wood as a renewable source of energy. A full account of the work already completed under this programme is provided in the report on Phase I of the Shenstone Lodge School Heating Demonstration.

The Phase I demonstration ran from March 1997 until April 1999. During this period it was not possible to operate the combustion system on a continuous basis. The main problem experienced during this time was the difficulty in securing a continuous supply of locally sourced wood chips to meet the manufacturer's specification. The key issue was the inability of forest-based chippers to produce sliver-free chips.

As an interim solution, wood chips produced as a by-product from a sawmill were imported from Cumbria. Whilst this overcame the problem of slivers, the moisture content of the wood chip was never able to meet the

manufacturer's specification of 30% moisture content. Importing wood chip from outside the area also failed to address the constraints restricting the development of a local wood fuel supply chain.

The Phase II proposal was brought forward to address the problem of fuel supply. It is based on the use of standardised manufactured wood pellets, which (with consistent characteristics in terms of size and moisture content) will avoid the problems experienced when using wood chip.

THE WORK PROGRAMME

The testwork undertaken at the site consisted of the long-term monitoring of the boiler and ancillary equipment by the site operator (school caretaker) for a three-month period and a more detailed boiler performance test.

Immediately prior to the assessment of the boiler performance, it was de-ashed and cleaned to provide best achievable performance and efficiency. For the testing, the boiler was operated at a steady state condition for as long as possible (at least one hour in duration per test). Over the test period the following parameters were monitored:

- Fuel feed rate, estimated from fuel feed per week
- Flue gas temperature
- Flue gas oxygen, carbon monoxide, nitrogen oxide, nitrogen dioxide and sulphur dioxide by Testoterm 33 analyser
- Gas bags for Cl-C5 gases and VOC's if applicable
- Carbon dioxide by Fyrite

- Observation of stack using Ringlemann charts
- Smoke and particulates via Bacharach pump and filters
- Water flow and return temperatures from energy management system
- Water flow rate from heat meter
- Heat output from boiler from heat meter
- Ambient and boiler case/cladding temperatures
- Observation of furnace/firebox.

A representative sample of the wood pellet-fuel fired during the testing was taken. A sample of the ash produced was also taken. The fuel sample was analysed for size and moisture (as the long-term samples). With additional analysis for calorific value (CV), approximate (moisture, ash and volatile matter), loss on ignition and ultimate (carbon, hydrogen, nitrogen and oxygen). The ash was analysed for loss on ignition and ash content.

From the measured data the boiler efficiency was calculated both by 'direct' and 'indirect', or simplified losses methods.

For the long term monitoring a simple step-by-step log sheet, a standard proforma specific to the site, was designed. In the case of Shenstone Lodge no additional monitoring equipment was required to be fitted, as a heat meter was already fitted as part of the previous work.

The specific areas of interest were:

- Fuel usage, in this case mass in tonnes
- Fuel type, species and source, in this case pellets
- Fuel supply and cost, if known

- Boiler heat output from measured by heat meter
- De-ashing/cleaning frequency and amount of ash removed
- Chimney visible smoke emissions
- Routine maintenance requirements, jobs performed and time
- Details of breakdown and problems with cause and solution
- Other general comments.

Further data was obtained by downloading from the boiler energy management system and heat meter to the Council via the modem link.

The completed forms were to be returned on a monthly basis along with a sample of wood fuel fired during the period. All the fuel samples were analysed for size distribution and moisture.



Figure.1 The pellet delivery process

CONCLUSIONS

This second phase of demonstration has shown that it is feasible to use wood pellets. Clear advantages over the use of wood chip have been demonstrated. The key conclusions that can be drawn from this stage of work are as follows:

The use of standardised fuel pellets.

The combination of the modifications to the automatic feed system and the use of standardised fuel pellets meant that the combustion system was able

to run continuously throughout the demonstration period. The problems caused by irregularity in the size of wood chips (in particular the inclusion of slivers) were avoided, enabling the supply of fuel to be continuous. In general the handling of the wood pellet was significantly easier. The delivery process was fully automated through the use of a hi-ab. A significant saving in labour was achieved through the fuel pellets being bagged at source and loaded directly onto the lorry. The average moisture content of 12% was significantly less than the moisture content of the wood chips used during Phase I, which, on average, had a moisture content of 38%.

Boiler Performance. The modifications undertaken to the boiler enabled it to work well at low outputs (56kW) and low turndown. This overcame one of the problems that had affected the boiler performance during Phase I. The overall efficiency of the boiler was good. In comparison to similar installations, it came second out of a total of nine. However, to compete with gas on a cost effective basis, the cost of the fuel pellets would have to be reduced from £60 per tonne to around £40 per tonne. As the demonstration is a stand-alone project without the benefits of economies of scale in terms of fuel supply, it is anticipated that this price could be achieved following market development.

Emissions. The combustion system performed well in terms of emissions. It achieved very low average carbon monoxide emissions with 63mg m⁻³ being observed. The average emissions of NO_x and SO_x were also low with 184mg m⁻³ and 1mg m⁻³ respectively being achieved. With regard to hydrocarbon emissions,

these were very low being below the analyser minimum detection limits.

Site management. The new system of fuel delivery worked well and caused the school the minimum disruption. Minor problems associated with noise, physical position, access constraints and fuel capacity could be overcome by repositioning the boiler on site.

Overall the demonstration has been successful and provides a sound basis upon which further work can be undertaken, both at Shenstone Lodge School and in the wider market.

POTENTIAL FOR FUTURE DEVELOPMENT

With regard to Shenstone Lodge School, it is recommended that the boiler be re-positioned in the existing boiler house where the old covered coal storage area could be utilised for the storage of wood fuel pellets. This would overcome the current minor operational problems and by increasing the storage area reduce the frequency of deliveries. It is also recommended that the school annex and the caretaker's flat could be included in the scheme. The feasibility of incorporating the swimming pool should also be investigated, as this could provide a useful heat sink to manage any surplus heat.

The other recommendation that is made on the basis of this work is that further research needs to be undertaken to explore the feasibility of setting up a local wood fuel processing plant to enable the cost of the pellets to be reduced to make them competitive with gas. This could be linked to the work being undertaken by British BioGen to explore the possibility of setting up regional cluster groups.

MONITORING WOOD HEATING PLANTS

CRE Group Ltd

OBJECTIVES

The overall aim of the project was to support the increased use of biomass heating plant in the UK by improving the quality and quantity of information available to suppliers and users. This aim was achieved by:

- Providing a qualitative assessment of the operational performance of a representative range of biomass heating installations including summaries of technical information.
- Providing good case studies for a range of installations addressing the varied market demands.
- **Collating performance data of existing installations so as to improve the performance and/or reduce capital and operating costs of existing and future installations.**
- Providing basic operator training and recommending methods of optimising/improving plant performance.

SUMMARY

There is a potential market for wood fired heating plants in the UK. However, the start up of new facilities has not been as expected. There exists much information on the technology behind this and it is now the non-

technical problems that are the main obstacles.

It is thought that the industry has become stagnant and for it to move on more plants will need to be built. In order to facilitate the construction of these plants this report has been produced. The report brings together a great deal of information on existing biomass heating plants providing detailed case studies and recommendations.

COST

The total cost of the project, £63,437 was met by the Department of Trade and Industry (DTI).

DURATION

24 months – July 1998 to July 2000.

BACKGROUND

There is generally recognised to be a large potential market for wood fired heating plants in the UK. A study by British BioGen in 1996 suggested this market could be 905MW per annum. However, the number of units installed in the 20 to 1000kW range in recent years has been disappointing. A considerable amount of research and development work to reduce the technical barriers to adoption has been undertaken to the point where suitable,

reliable equipment is now available for some of the major markets. Indeed, the major barriers to adoption are now non-technical eg economic, fuel supply logistics, marketing, industry infrastructure, information, etc. It is often stated that for the industry to move forward 'plant has to be installed'.

British BioGen and the associated biomass heating industry are conducting a substantial marketing programme to address this situation, supported by DTI. The project involves setting up regional clusters of biomass installations, publicity material, design and best practice guidelines, demonstration reporting and other initiatives. Early work within this project has identified a lack of good case studies to support this marketing effort, and also technical data to assist those preparing design guidelines, producing designs and endeavouring to improve the performance of installed and proposed plant.

THE WORK PROGRAMME

This project seeks to address this situation by monitoring and publicising a number of existing and proposed installations. The project is concerned only with the use of forest residues, short rotation coppice and the various wood fuel products arising from woodland management and primary processing as heating fuels.

Ten wood burning boiler sites were chosen for monitoring and performance trials. The boilers were in 'clusters' and represented a cross section of equipment from both UK and foreign manufacturers which vary in size ratings. The operators monitored the boiler systems over one or two heating seasons and a more detailed performance test that required a site visit was undertaken.

Operator Long Term Monitoring

For the long term monitoring a simple standard pro-forma, specific to the site, was designed. This was filled in on a weekly basis. A water meter connected to a heat meter integrator was fitted. A maximum and minimum thermometer and hours run meters on fan and wood feed augers were also fitted where applicable.

The specific areas of interest were:

- fuel usage, in cubic meters or kilograms or derived from hours run meters
- fuel type, species and source
- fuel size, subjective assessment to change
- fuel moisture content, subjective assessment to change
- fuel supply and cost, if known
- boiler heat output from heat meter
- de-ashing/cleaning frequency and amount of ash removed
- power usage, fan run, auger run and total hours run meters
- chimney visible smoke emissions
- routine maintenance requirements, jobs performed and time
- details of breakdown, problems, cause and solution
- other general comments.

The completed forms were returned on a monthly basis along with a sample of wood fuel fired during the two test periods. All the fuel samples were analysed for size distribution and moisture.

Performance Test Procedure

The boilers were operated at a steady state condition for as long as possible, at least one hour in duration per test. Over the test period some or all of the following parameters were monitored at each site:

- flue gas temperature
- flue gas oxygen, carbon monoxide, nitrogen oxide, nitrogen dioxide and sulphur dioxide by Testoterm 33 analyser
- gas bags for C1-C5 gases and VOC's if applicable
- carbon dioxide by Fyrite (absorption into caustic potassium hydroxide solution)
- observation of stack using Ringlemann charts
- smoke and particulates via Bacharach pump and filters
- water flow and return temperatures from heat meter
- water flow rate from heat meter
- boiler heat output from heat meter
- electrical power consumption
- ambient and boiler case/cladding temperatures
- observation of furnace/firebox
- density of as-fired wood fuel
- flue gas flow rate.

A representative sample of the wood fuel fired during the testing was taken. A sample of the ash produced was also taken. The fuel samples were analysed for size and moisture (as the long-term samples) and additional analysis for calorific value (CV), proximate (moisture, ash and volatile matter) loss on ignition and ultimate (carbon, hydrogen, nitrogen and oxygen). The

ash was analysed for loss on ignition and ash content.

From the measured data, the boiler efficiency can be calculated both by the 'direct' and 'indirect' or simplified losses methods. The 'direct' method involves the comparison of energy input from fuel to energy output to water measured by the heat meter. The 'losses' method aims to quantify all major energy losses from the boiler system, with the efficiency calculated by the energy input from the fuel minus all the determined energy losses.

RESULTS AND CONCLUSIONS

- All the monitored boilers fell into class 2 efficiency standard (greater than 63 to 72%). However, two boilers achieved class 3 efficiency standard (greater than 73 to 82%) but on one site the CO emission criteria was not met.
- Ranges of boiler outputs were found, between 13 and 94kW on a gross indirect basis. The outputs lie across a large range of manufacturers maximum continuous ratings (MCR), between 12 and 98%, with the majority of plant operating within the range of 35 to 70% MCR's.
- The CO emissions had a large variation, depending upon the site. For sites with batch fed boilers the CO emissions ranged from 8,000 – 12,500mg/m³. For sites with stoker fired boilers the CO emissions ranged from 63-4,000 mg/m³.
- The NO_x emissions were all below the achievable releases to air of 300 mg.m⁻³ NO_x stated in HMIP Guidance Note S2 1.05. This was

due to low fuel nitrogen and low combustion temperatures.

- All SO₂ emissions were low, well below the achievable releases to air of 300 mg.m⁻³ SO₂ stated in HMIP Guidance Note S2 1.05, due to the low sulphur content of the wood fuel.
- On several sites it was clear that further instruction, both written and verbal, for the operators would have been of benefit to the overall operation of the boiler systems. Examples of this are de-ashing and boiler tube cleaning frequencies, one site was de-ashing too often resulting in un-burnt wood being removed, whilst others were cleaning boiler tubes once per year or not at all, causing high flue temperatures and flue way blocking.
- Technical information and documentation about the boiler, commissioning and operation is also covered within BS EN 303-5.
- On a lot of the boiler control systems facilities existed for operator adjustment to the wood firing rates, both continuous and slumber, and the combustion air flow rates. This allowed the operator to make changes in the event of large changes in fuel quality such as moisture. Thus the combustion could be tuned 'by eye' looking at the fire flame and stack. From the site visits for the testing it was apparent that many of the boiler system had been commissioned in this way, flue gas analysis, especially CO and thus efficiency measurements had not been carried out.
- Optimum combustion conditions to reduce CO emissions and excess air levels, whilst

maintaining or improving boiler efficiency and output, in this case are rather hit or miss. To maintain optimum combustion conditions and efficiency the use of a simple combustion analyser and good reliable repeatable fuel quality is recommended.

- A range of wood fuel types, sizes and moisture levels were burnt across all the trial sites. Fuel was sourced and provided locally at 5 sites by the owner operators at little or no cost for the wood. Costs for the production of the fuel, mainly the manual handling and labour, were absorbed by the use of retained staff in a number of cases.
- The performance of many of these boilers in the field falls short of the upper performance bands required by BS EN303-5: 1999. This may give an undue pessimistic view, however, under optimised conditions many of the boilers would perform far better.

POTENTIAL FOR FUTURE DEVELOPMENT

The data obtained was collected under non-ideal testing conditions and with low boiler ratings and loads in many cases. It would be expected that the boilers operating under ideal laboratory test conditions at full rated outputs would achieve better efficiency performance and lower emissions levels.

DEVELOPMENT OF CORDWOOD BOILER SYSTEM

Nordistribution Limited

OBJECTIVES

- To examine user and technical requirements for heating from cordwood combustion.
- To evolve a specification for a boiler and accumulator tank system for cordwood fuelling, at a range of sizes. This will involve examining both the UK and overseas markets.
- To design the boiler and accumulator tank, with combustion and system controls as required.
- To manufacture a complete prototype boiler/tank unit for test.
- To test the prototype, ideally on a real site.
- To alter the design as necessary to achieve good operation and realistic costs.
- To cost the production over a range of sizes.

SUMMARY

Wood fuel heating in the UK has usually been by means of logs, often in the form of open fires or wood-burning stoves. In some cases these provide a full heat supply for the building. The logs for this have to be short in length, but this means that they are expensive

to produce and very time-consuming to handle and stack. This is where the Cordwood Boiler can provide a useful alternative, as it does not require such small logs.

The purpose of this project was to develop a Cordwood Boiler and build a prototype that could then be tested at a real site. Once developed, the boiler was manufactured and installed at Chithurst Buddhist Monastery, where it has been running on site, providing the heating and hot water for the residents.

COST

The total cost of this project was £38,530, with the Department of Trade and Industry (DTI) contributing £19,265 and Nordistribution Ltd the balance.

DURATION

27 months – April 1999 to June 2001

BACKGROUND

Historically, wood fuel heating in the UK has been by means of logs. Recent emphasis has brought wood chip to the fore. Wood chip is often more suitable for larger commercial sites than for domestic use, where logs are more commonly associated, often in the form of open fires or a wood-

burning stove. The common split logs are ideal for such use, but are expensive to produce and time-consuming to handle and stack.

This is where the benefits of cordwood become apparent. Firewood is initially produced and extracted in 4ft or 2m lengths, known as cords, which are then processed into logs.

Advances have been made in Scandinavia and Austria in log boiler design. Typically these units only accept logs up to a length of 500mm. The combustion system has been developed from a crude updraft system to the more efficient cross-draft, with a better downdraft system. The latter have ceramic grates incorporating secondary air heating. Although the performance is good, the fuel length specification is very restricting. The logs must lie horizontally, due to burning characteristics that cause the fire to go out.

It can therefore be seen that there is a real need for development of such a burner as the Cordwood.

THE WORK PROGRAMME

After reviewing the available technology, the chosen solution was for a boiler with fuel hopper, cross combustion and secondary ceramic combustion zone (with manually controlled primary and secondary air inlets for maximum efficiency). The heat exchanger was the smoke pass type with easy access for de-ashing. The boiler was set with basic controllability that could be adapted as necessary.

The Chithurst Monastery was selected for field trials. The monastery has a large area of woodland, which is felled in summer to provide wood for the

winter heating needs. As the felled wood could be hand chopped into suitable sizes, the need for machinery for further processing was eliminated. Also, due to the communal living style of the monks, the usual constraint of stoking the boiler was easily overcome by the numbers available to carry out this task.

An accumulator tank was provided and fitted with the boiler so that the heat could be stored as hot water. This allowed the system to be optimised and sized to spread the availability of heat, maximise the efficiency of combustion, increase the substitution of fossil fuels and so improve the cost effectiveness and environmental performance of the boiler.

The boiler was then manufactured, installed and commissioned at Chithurst Monastery in order to carry out the trials on the system.

RESULTS

The peak output of the boiler was measured at 21kW; the boiler had been designed with a rating of 50kW.

The current method of stoking the boiler can account for the disappointingly low output. The boiler was designed to be stoked twice a day and to be completely filled on both occasions. However, the practice currently is to stoke the boiler on average five times a day and to fill only approximately a third of the boiler.

The current method of filling only about a third of the boiler (using 18kg of wood, five times a day) uses 90kg of wood over 24 hours. If the boiler were completely filled, then 54kg of wood would be used twice a day, totalling 108kg of wood. This would result in much higher temperatures for shorter periods of time, but the accumulator

stores the hot water until there is a demand for it. Burning the wood at higher temperatures would thus result in improved combustion efficiency.

The measured energy output of the wood was a relatively low figure. This figure could be further improved if the actual moisture content of the wood was recorded, as this directly affects the calorific value. In this case the moisture content of the wood was assumed to be 40% (as the wood had been harvested in the autumn to be burned that winter, when the wood should have seasoned to reduce the moisture content).

CONCLUSIONS

The project succeeded in achieving its aim to design and manufacture a Cordwood Boiler. The prototype boiler has been running on a real site, meeting the heating and hot water needs for a large domestic dwelling.

The use of cordwood has had practical advantages for the monks at Chithurst Monastery. It has enabled the wood on the land to be used to meet the heating and hot water needs.

The boiler output could be further improved by stoking the boiler in the correct quantities of twice daily, with wood at an improved moisture content of approximately 25-30%.

The boiler efficiency would be directly affected by an increase in output.

Currently the high moisture content of the wood results in a large proportion of the energy being expended in drying the wood, which naturally affects the output of the boiler.

Greater accuracy could have been included in the calculations if the actual moisture content of the wood had been recorded, as this directly affects the assumed calorific value of the wood, on which the calculations were based.

POTENTIAL FOR FUTURE DEVELOPMENT

With regard to the daily running of the boiler, it is recommended that it is run with twice daily stoking. This will allow the boiler to peak at higher temperatures and to run efficiently.

It is recommended that further testing be done on the output of the boiler over a longer period, whilst using the current stoking method of five times a day. Once these results have been recorded, the boiler should then be stoked correctly twice daily and the results.

INTRODUCING WOOD PELLET FUEL TO THE UK

Renewable Heat & Power Ltd

OBJECTIVES

- To help establish a wood pellet industry in the UK.
 - To review the historic growth and current status of the wood pellet industry in other European countries and North America.
 - To review UK standards, legislation, and regulations and developing UK voluntary standards for biomass pellets and appliances.
 - To identify and quantify markets for pellet heating in the UK.
 - To organise a series of workshops, seminars and other events to demonstrate pellet burning appliances in order to raise awareness of the technology.
 - To carry out trial pelletisation of a variety of biomass feedstocks available in the UK and help establish fuel palletising facilities within the UK.
 - To help establish a number of demonstration installations of pellet-fired appliances.
 - To undertake a promotional campaign for wood pellet fuel.
- To compile resource directories for pellet fuel and pellet-burning appliances in the UK.

SUMMARY

Wood pellets are compressed wood, usually made from sawdust and shavings (although they can be made from any biomass material). The wood pellet industry has been established in Scandinavia and North America for over 20 years. As a result, wood pellet-fired appliances are highly reliable and tens of thousands of them are in operation.

Before commencing this project, the use of wood-fuel pellets was largely unknown in the UK. There was no fuel pellet production capacity, nor any pellet appliances on the UK market. This project has addressed a wide range of technical and non-technical issues to promote wood pellets and to help establish a wood pellet industry.

COST

The total cost of this project was £187,731, with the Department of Trade and Industry (DTI) contributing £74,043 and UK industry and the EC's ALTENER Programme the balance.

DURATION

24 months - April 1999 to April 2001

BACKGROUND

Wood pellets are now a major fuel resource for heating in many parts of Europe as well as in the US and Canada. Wood pellet-fired heating also has the potential to make a significant contribution to the UK's energy needs.

The wood pellet industry has been established in Scandinavia and North America for over 20 years. Wood pellet fired appliances are thus now highly reliable, with tens of thousands of systems in operation.

Wood pellet boilers and room heaters are highly automated. They have automatic ignition and are well suited to meet varying load demands. All pellet appliances have thermostatic controls or can be operated on a timer. This means that the level of convenience is equivalent to that of oil-fired heating systems, but wood pellets have added environmental benefits. Because the rate of fuel feed and the amount of air for combustion are controlled precisely, pellet appliances achieve very high efficiencies (typically >90%), in comparison to that of an oil-fired system.

Wood pellets are compressed wood made usually from sawdust and shavings. However, they can potentially be made from any biomass material and hence have the potential to be sourced from locally unused material, which can give considerable benefit to the local economy.

THE WORK PROGRAMME

A review of how the wood pellet industry became established in other European countries and North America and the current status of those industries was carried out. Interested parties in the UK were identified, and British BioGen established a Biomass Pellet Network (consisting of approximately 250 names of interested individuals). Standards, Legislation and Regulations effecting the production and use of wood pellet fuel in the UK and wood pellet appliances were reviewed. An overview of the potential markets for biomass pellet appliances in the UK was investigated. The first UK Seminar on Wood Pellet Fuel was held in September 1999.

An assessment of biomass resources in the UK was undertaken which looked at the following potential feedstocks: primary processing residues and secondary raw materials, recovered wood and biomass waste, forestry residues and energy crop products and straw. A more detailed resource survey was carried out in South Wales and the South West. A programme of identification and quantification of markets was also carried out. Pelletisation trials were carried out using a range of pelletisation equipment and a range of biomass feedstocks that are found in quantity in the UK.

Help was given on commercial considerations in terms of UK pellet production and installation of pellet-fired equipment. A number of training events were given to installers and service engineers on brand-specific pellet burning equipment. A series of

events were held where wood pellet technology was explained and demonstrated and a promotional campaign was undertaken to raise general awareness of the use of wood pellet fuel.

RESULTS

This project achieved the following:

- UK voluntary standards for wood pellet fuel and combustion appliances have been developed.
- The first seminar dedicated to wood pellets in the UK was held, attracting over 130 people.
- A database of about 250 individuals in the UK with an interest in wood pellet fuel has been compiled.
- Help was given in the establishment of a number of sources of UK manufactured wood fuel pellets including the construction of a 5te/hr pellet mill in South Wales.
- Pelletisation trials on equipment suitable for pellet production in the UK at a number of scales, using a wide variety of biomass materials available in the UK, have been undertaken (including preliminary trials using a grass mill for seasonal production of wood pellet fuel).
- Agreements have been made with a number of pellet stove and boiler manufacturers and UK companies to import equipment into the UK, and a number of UK companies are currently developing pellet appliances.
- About a dozen pellet-burning appliances are now operating the

UK (with many more planned to be installed over the next year).

- Six heating engineers have been trained in the general installation of wood pellet-fired appliances and in brand-specific appliances.
- An analysis has been made of the economics of wood pellet fuel in a UK context.
- A general resource assessment for the UK and a detailed resource assessment for two specific regions of feedstocks for biomass pellets have been compiled.
- A promotional campaign is underway, both for brand-specific equipment on a local level and for the generic promotion of the concept of heating with wood pellets at a national level.
- A centralised information service and website have been set up to deal with all aspects of promoting wood pellet fuel.

CONCLUSIONS

- The potential for a low cost feedstock of clean wood waste coming out of the waste sector is great. However, it is clear from pelletisation trials from this project and elsewhere that a critical issue in the acceptance of these materials is quality control procedures to ensure that there are no contaminants within the feedstock.
- The lack of an organisation in the UK with a specific remit to promote the use of wood pellet fuel at all levels will retard the expansion of the wood pellet industry in the UK. Most European countries now have a

'Pellet Club': a trade association for the wood pellet industry.

- The current Building Regulations (Document J) have not taken account of the coming into being of a class of forced draft appliances of low output (such as pellet-fuelled room heaters). The present minimum recommended size of 125mm diameter for any solid-fuelled appliance is inappropriately oversized for most pellet stoves and also represents an unnecessary cost burden.
- In general, the economics of wood pellet fuel in the UK look promising. Wood pellet fuel is competitive with oil and LPG in the UK at the time of writing this report, although the higher capital cost of pellet-fired appliances (in comparison with fossil fuel boilers) is a major barrier to the expansion of the wood pellet industry in the UK.
- The favourable fuel costs coupled to the environmental benefits of heating with woodfuel and the fact that the wood pellet industry could make a substantial contribution to the rural economy imply that an emerging wood pellet industry in the UK has a good chance of becoming a major renewable energy sector.

POTENTIAL FOR FUTURE DEVELOPMENT

A number of actions are required to help the expansion of the wood pellet industry in the UK over the next few years. These include:

- The introduction by the UK government of a capital grant scheme for biomass heating systems.

- More work on Quality Assurance schemes to ensure that waste wood from the waste handling sector is reliably sorted to exclude any material not complying with the present and likely future European descriptions for 'biomass fuel'.
- Generic promotion at all levels of the use of sustainably produced biomass fuels in substitution for fossil fuels.
- Further research and development by UK appliance and boiler manufacturers to develop new combustion hardware.
- Undertaking work with the Building Research Establishment to confirm the suitability of 100mm flues and chimneys for pellet-fuelled room heaters.
- Research into seasonal conversion of grass mills and sugar beet mills to wood pellet production.
- Research into the distribution and delivery of wood pellet fuel to consumers in the UK at various scales.
- The wood pellet industry has the potential to become a substantial industry in the UK over the next few years. The examples of other countries suggest that pellet fuel is, by its nature, sufficiently specialised that it requires its own generic promotion. There are European initiatives to accomplish this, which the UK should support.

The role of a Pellet Trade Association, or a specialised sub-section of an existing Trade Association would be the following:

- To run a central information service on all aspects of wood pellet fuel including lists of manufacturers of appliances and suppliers of wood pellet fuel.
- To develop an accredited training programme in wood pellet heating, covering both pellet stoves and central heating systems, similar to that of the CORGI training for gas-fired appliances in the UK and the Heath Education Foundation in North America.
- To represent the Wood Pellet Industry's interests at national government and local government level.
- To develop and refine standards on pellet fuel and appliances to comply with the latest legislation.
- To co-ordinate all promotional activities of wood pellet fuel.

CARTRIDGE FURNACES FOR THE BIOMASS INDUSTRY

Energy for Sustainable Development (ESD) Limited

OBJECTIVES

- To develop a new cartridge feed system that does not use a grate, but achieves better fuel/air mixing, higher heat release rates, and good ash separation; at least 1MW/m³ with high boiler efficiencies and low emissions.
- To prove that this system has the potential to be:
 - o **cost effective for installation at the 50-100kW level**
 - o convenient to use with an acceptable heating cost to consumers
 - o capable of competing with oil/gas burner units.

SUMMARY

To improve the market prospects for wood fuel, and help achieve the biomass industry heat installation targets of 900MW/yr, it is necessary to offer better combustion equipment and cheaper fuel delivery to the consumer. The fuel must also improve the cost competitiveness of the heat supplied, relative to competing energy supplies.

While wood fuel manufactured from wood industry wastes is a potentially cheap source of energy, the grate-

based approach to combustion is not a suitable platform for providing competitive heat supplies. The solution is two-fold:

- more compact combustion systems, with greater outputs and efficiencies
- denser fuel formats that can be easily handled with existing equipment.

Briquettes represent a possible fuel format. Manufactured from wood by extrusion in 20cm lengths and delivered on pallets, the energy density (~5MWh/m³) approaches that of hard coal.

The Cartridge Burner project set out to design and test an entirely new combustion system that could use this high volatile fuel for water heating. A new furnace/boiler unit was successfully constructed on the basis of a unique horizontally opposed combustor design using 3x3 briquette 'cartridges' of commercially available briquettes.

COST

The total cost of this project was £49,500 with the Department of Trade and Industry (DTI) contributing £24,414 and ESD Ltd the balance.

DURATION

18 months - June 2000 to November 2001

BACKGROUND

ESD has been commercially involved in the development of biomass energy for a number of years, both by itself, and in partnership with BEST Pty in Australia. The provision of fuel from fresh, and waste, biomass; and the methods of generating clean heat, and power, from these fuels, have required that a number of new technologies be developed. ESD and BEST have successfully introduced both new combustion and gasification systems to the market.

The direct use of biomass in small boiler houses to provide heat at a market competitive rate of 2p/kWh is a particular challenge. Most current systems, based on logs or wood chips, struggle to reach this figure. ESD and BEST are developing thermally assisted compaction processes for briquetting which have the potential to fuel boilers at, or below, this price provided that the necessary combustion equipment is available.

Wood chips have yet to establish themselves as a competitive heat market fuel. Equipment costs greater than £100/kW make conversion expensive, but with boiler efficiencies of 75%, or less and fuel costs >£40+/ton, the delivered cost of biomass heating can easily increase from a budget 1.75p/kWh, to well over 2p/kWh.

The manufacture of wood fuels as a coal substitute, has worked - to a limited extent. Where wood wastes arise on site and can be burnt to substitute for purchased fuels there is

an incentive to manufacture pellets, or briquettes.

However, this requires the use of grate based systems, overfed, underfed, mechanically or spreader stoked. These typically have furnace heat release rates of only 0.25MW/m³.

The major use of the grate is to mix the fuel and air, and to provide a means for separating the unburnt fuel/ash from the fresh fuel in one of several configurations – updraft, downdraft and cross draft – usually with the fuel falling by gravity.

Where a grate is not used, as in hearth furnace, the ash either accumulates, or is entrained out of the furnace into the heat exchanger flues. It can be separated in these by impingement, or by a subsequent cyclone/bag filter arrangement. Grates are normally beneficial in ensuring that there is a high degree of carbon burn out in the furnace, but specific outputs are limited.

THE WORK PROGRAMME

The initial focus of the work was the concept development of a burner system that could meet the functional specification in two possible arrangements, horizontal and vertical.

The chosen briquette configuration was an extruded log, cut off at 20cm lengths, and typically supplied to the UK market as 'Heat Logs'. These use a 65mm die and produce an octagonal briquette (square with knocked off corners) with a central hole of approximately 12mm. The density of this product is normally >1000kg/m³ which gives an approximate weight for each briquette of 850g. Twelve briquettes are normally sold as a '10kg' pack. The vertical configuration was perceived to be the mechanically

simpler arrangement, but from consideration of feed door height, and fuel feeding, was only expected to be capable of handling smaller 'cartridges' - bundles of briquettes – for instance, a 3x2 cartridge of six briquettes weighing ~5kg. The horizontal configuration would be capable of handling larger cartridges.

Briquettes have a heating value (output at 80% efficiency) of 4kWh/kg. To achieve an output of 50kW a modular furnace unit would need to burn 12.5kg/hr briquettes an hour, which would favour the horizontal configuration. In a 3 x 3 (9) briquette cartridge (~8kg) configuration this would require re-fuelling (2 cartridges) approximately every 1.5 hours.

RESULTS

Overmoor Farm has a small heating network/CHP system and the intention was to install the boiler as a winter heating component of this system.

Prototype tests had shown that this configuration was able to achieve the high heat release rates needed, depending on the proximity of the burning 'faces' of the briquettes.

Successful ignition required that the cartridges be brought close together. Once lit the output of the cartridges furnace rises rapidly. Initial trials on the 'single fill' prototype showed that the gap between the cartridges should be kept to a minimum, consistent with adequate air supply. If the gap increased, then output declined. Air could be supplied in a variety of configurations, with ash entrained into the firebox where it impinged on the back wall and fell to the furnace floor. Clean, hot combustion was achieved with no chimney.



Figure 1 Final configuration of cartridge burner installation at Overmoor farm

The design met the basic requirements of the project brief for low box volume, high efficiency, low emissions and safe operation. The additional requirements of:

- auto start
- output modulation
- low attendance
- easy refuelling

were also met after a considerable amount of work was done to balance the reaction rates in pyrolysis, flaming combustion and char burn out phases. When these rates are properly controlled the output of the furnace is stable. Normally, char burn out is the slowest step and significantly reduces potential output, particularly on grate-based systems.

Auto start was accomplished with gas, but could also be handled electrically. A major concern was achieving output modulation. This was eventually accomplished, as planned, by control of airflow rates and regulating the relative position of the briquette cartridges. Automation of the self-feeding action was also incorporated to demonstrate how attendance would be minimal while re-fuelling/de-ashing.

Further optimisation of fuel burn and air supply rates is required to reduce CO emissions below the 80ppm

required by HMIP S2 1.05 for large combustion equipment, however, the performance of the unit warrants a Class 3 rating under the BS EN303-5 which applies to small boilers of this type.

The development of the Cartridge Burner has successfully demonstrated that there is an alternative to grate based systems for wood fuels. It can deliver high, controllable furnace outputs ($>1\text{MW/m}^3$) with boiler stack losses below 15%, and provide the basis on which wood fuel can be successfully introduced to a wider market. The projected cost of briquettes in volume manufacture ($<£75/\text{ton}$) makes a competitive cost of 2p/kWh for biomass heating achievable.

CONCLUSIONS

The main conclusion is that the Cartridge Burner concept works well for biomass water heating. The low moisture content and high reactivity of briquetted wood fuel make it possible to burn the fuel completely and cleanly in a small furnace, and to fit high efficiency heat exchangers. High heat release rates (1MW/m^3) combined with low stack losses ($<15\%$) mean that the unit has the potential to be:

- cost effective at the 50-100kW level with installation costs below £100/kW
- convenient in use with biomass heating costs approaching 2p/kWh
- capable of attracting customers away from competing oil/gas fuelled units.

Further work is needed to develop the concept to a practical system for

demonstration to the UK biomass industry.

POTENTIAL FOR FUTURE DEVELOPMENT

The basic technical parameters of the Cartridge Burner have been validated through this research project. It is recommended that further work include:

- development, promotion and demonstration of low cost wood fuel briquetting methods
- refinement of mechanical and control features of the Cartridge Burner
- longer term water heating trials under UK conditions
- type approval for the Burner under BS EN 303-5
- investigation of Burner manufacturing options and costs
- establishment of demonstration biomass water heating project(s).

INVESTIGATION INTO THE PRACTIBILITY OF BURNING BIOMASS ON UNDERFEED STOKERS

Ashwell Engineering Services Ltd (with EMC - Environment Engineering Ltd)

OBJECTIVES

- To significantly reduce the capital and operational costs of biomass heating systems, whilst maintaining or improving on existing biomass combustion efficiency and emissions.
- To improve the operational acceptability of biomass burning.

SUMMARY

To achieve the project aims, an existing underfeed stoker was modified to burn biomass pellets.

The operational acceptability of underfeed stoker plant is already well proven, as is the underfeed principle of clean combustion. The potential for low capital cost, combined with inherent clean-burning technology and ease of operation, makes the converted underfeed stoker an ideal choice for burning biomass pellets.

The report is based on the biomass fuel being in pellet form (to reduce storage system handling/transportation problems and improve the economics of delivery in comparison with wood chip systems).

The project used a 100kW_{th} output underfeed Ashwell air heater. The main test fuel was commercially

available wood pellets. Problems with pellet quality and supply were, however, encountered during the testing.

Initial trials were undertaken to assess the requirements for using pellets instead of coal. Modifications to the retort and secondary air supply were made. Performance testing was then undertaken.

A representative sample of the wood pellet fuel fired during each series of tests was taken. A sample of the ash produced was also taken. The pellet fuel and ash samples were analysed.

From the above data, the boiler efficiency was calculated. Boiler output and combustion efficiency were also calculated using experimental data.

The conversion of coal plant to fire wood pellets, at similar outputs with similar or higher boiler efficiencies with lower emissions, was achieved.

COST

The total cost of this project was £70,400, with the Department of Trade and Industry (DTI) contributing £33,978 and Ashwell Engineering Service Ltd the balance.

DURATION

24 months - June 2000 to June 2002

BACKGROUND

At present there are still large numbers of coal-fired plant operational throughout the country with significant numbers in the 'old mining' areas. Many of these units are being removed and replaced by other fuel-fired units well before the coal-fired equipment life has expired.

If a relatively low cost conversion kit can be developed to enable underfeed stokers to burn biomass, this will negate the huge capital cost otherwise needed to rip out perfectly good underfeed coal-burning plant and replace it with new biomass burning plant. The operational acceptability of underfeed stoker plant is already well proven, as is the underfeed principal of clean combustion. The potential for low capital cost (combined with inherent clean-burning technology and ease of operation) means that the converted underfeed stokers are an ideal choice for burning biomass pellets.

Several hundred underfeed stokers that burn coal exist in the UK. If a low cost conversion kit can be developed, it would promote the biomass market by enabling its use on hundreds of existing coal-burning sites as an environmentally favourable alternative to coal. It is believed that the capital cost for a new converted underfeed stoker plant will be a fraction of the cost of an equivalent wood chip burner plant. It is therefore our objective to develop a conversion kit to facilitate the combustion of biomass on underfeed stokers.

The project is based on the biomass fuel being in pellet form to reduce

storage system

handling/transportation problems and to improve the economics of delivery in comparison with wood chip systems.

The Ashwell Compac consists of a tubular-designed heat exchanger, which is fitted onto a modular base section that includes the underfeed stoker screw mechanism and forced draught air fan. Fuel is fed via the screw from the hopper into the base of the retort beneath the fire bed. Fuel is forced upwards in the retort toward the burning zone where forced draft primary combustion air is injected from the tuyere air slots.

Further air (secondary air) is supplied above the fire bed to complete combustion in a smoke-free manner. Both primary and secondary air are fed from the one fan via separate dampers to the retort plenum chamber and the above bed combustion zone.

THE WORK PROGRAMME

The scope of work within the project consisted of:

- Basic stoker retort/combustion investigations
- Design of parameters for conversion kits within 50-150kWth range
- Pilot scale trials/demonstrations
- Dissemination
- Reporting.

A sealed fuel hopper, for manual firing, was fitted on initial trials, followed by a bunker tube and screw for automatic bunker to boiler firing.



Figure. 1 8mm diameter pellets

The initial trials were undertaken using an existing coal fired unit of 75kW_{th} thermal output. From the results, initial design parameters were drawn up for inclusion in the new test 100kW_{th} heater unit. The new unit was manufactured, and commissioning was carried out using the new tuyere arrangement, forced draft air fan and over fire air arrangement. A selection of fuel types was tested during the trials, and two were selected for use throughout the trials.

Plant efficiency and emission testing trials were then carried out. The testing was undertaken at differing times with both of the woodfuel pellet types. In both series of tests similar procedures were followed. Testing was undertaken using a simplified method based on BS 845.

The boiler was operated at a steady state condition for as long as possible (at least one hour per test). Over the test periods the following parameters were monitored:

- Flue gas temperature
- Flue gas oxygen, carbon monoxide, nitrogen oxide, nitrogen dioxide and sulphur dioxide by Testoterm 33 analyser
- Spot carbon dioxide measurement by Fyrite

(absorption into caustic potassium hydroxide solution)

- Observation of stack using Ringlemann charts
- Smoke and particulates via Bacharach pump and filters
- Ambient and boiler case/cladding temperatures
- Observation of furnace/firebox.

CONCLUSIONS

- Successful conversion of coal plant to fire wood pellets at similar outputs with similar or higher boiler efficiencies with lower emissions.
- Cost of retrofit kit and installation estimated at £4000.
- Pellet fuel is CO_2 neutral.
- High combustion efficiencies obtained (+99%).



Figure. 2 Ashwell Compac air heater unit firing wood pellets

- Boiler efficiencies comparative to coal firing with 8mm diameter pellet.
- Boiler output comparable to coal firing, woodfuel feed rate easily

adjusted to increase fuel input, and no de-rating of the boiler anticipated with the scale 75 to 150kWth.

- Much reduced sulphur dioxide emission level compared to that operating with coal.
- Little fuel handling problems encountered on 8mm pellets, good degradation characteristics and low dust levels.
- Low fuel moisture levels.
- Lower ash levels than coal enabling less frequent de-ashing and de-clinkering.
- No formation of clinker observed firing 8mm diameter pellets.
- Lower maintenance expected due to lower moisture and corrosive chemical composition. Less wear due to softer fuel.
- Heat output costs of 2.1 to 3.0 pence per kWh.
- Undertake a retrofit conversion at a customer site to enable further feedback/development.
- Trial pellet fuel on larger under feeds to extend range of appliance able to cope with wood pellets.
- Guarantee of pellet fuel quality.
- Increase availability of pellet fuel.

POTENTIAL FOR FUTURE DEVELOPMENT

- Operate boiler plant with a much-reduced primary air fan size (coupled with a separate higher pressure low volume fan supplying the over fire air nozzles instead of the large volume low pressure fan fitted). Fitting reduced fan sizes may benefit the capital and running costs of the boiler.
- Operate boiler at full boiler output without thermostat stopping firing to allow steady state combustion conditions to be established.
- Trial pellets on a similar under feed compac unit with water boiler.

DEVELOPMENT OF STOKER-BURNER WOOD CHIP COMBUSTION SYSTEMS FOR THE UK MARKET

Econergy Limited

OBJECTIVES

- To carry out a hardware development exercise on the basic stoker-burner design to enhance its performance, increase operational acceptability and improve reliability and availability.
- To obtain a spot efficiency of 80%, seasonal efficiency of 65%, moisture tolerance: 75% output maintained at 40% mc.
- To have no intervention between fuel deliveries (time varies according to size but 1/week indicative); better control of ignition front on variable mc.
- To maintain a cost effective single-phase option.

SUMMARY

There is considerable interest in heating from biomass in the UK. Stoker burners provide a flexible and cost effective option for wood chip heating. However, currently in the UK there are no designs for stoker burners with the risk that all sales will go to foreign manufacturers.

Therefore, Econergy has decided to develop a stoker burner that will be cost effective and suited to the UK

market, to further penetrate the market for wood chip heating in the UK.

Econergy procured all materials and designed and constructed one operational prototype stoker burner rated at 120kW_{th}, along with a full test rig and all necessary combustion controls. A test rig was designed and built to enable prototype test and development under controlled conditions.

COST

The total cost of this project was £58,700, with the Department of Trade and Industry (DTI) contributing £29,350 and Econergy Ltd the balance.

DURATION

21 months - April 2000 to December 2001

BACKGROUND

Stoker burners provide a particularly flexible and cost effective solution for wood chip heating that is appropriate to a wide variety of contexts. The application of this technology could significantly increase the market penetration of wood heating in the UK because of its relatively low cost. The high level of interest in biomass heating at the time of writing is

resulting in considerable sales of such units in the UK.

In addition, the products that are available from countries such as Finland and Sweden are designed for their market conditions. While this equipment may be viable in the UK, a number of modifications could be made to improve its performance and utility in a UK context without compromising its cost-effectiveness. Therefore, this project was intended to develop a new, improved design of stoker burner that would be at least part-manufactured in the UK to suit UK market conditions.

THE WORK PROGRAMME

Two main areas of work were undertaken:

- the modification of the burner head
- the development of control hardware and a control strategy.

When looking at burner head modification Econergy modified the existing burner head design, treating the base liner as being primary air, and the cheeks as being secondary air. This was accomplished by partly dismantling the burner head and welding in segregation plates to prevent the original air supply from the plenum reaching the secondary air. Then an air manifold system was fabricated to feed air through tubes across the now primary air plenum into the air space behind the cheeks.

This had the incidental effect of increasing primary air preheat, one of the project objectives, by reducing flow through the plenum, which acts as a preheating system. This gave undergrate temperatures of 250°C at full load, which was felt to be adequate.

The original air fan was discarded in favour of two variable speed fans, enabling automatic control of the air supplies. These units use a 24VDC power supply, with 0-10VDC control loop to an internal controller. They can thus interface directly with the SCADA system.

The control hardware and strategy were then looked at. Additional control hardware was fitted including a Lambda oxygen (O₂) sensor in the flue and a number of thermocouples to measure boiler flow, return, flame and flue temperature. Air flow meters and CO monitoring were also fitted but proved impractical and were not used in the control package. A Toshiba inverter with single-phase 230V input and 3-phase output was used throughout the trials to control the fuel stoking auger motor.

Initially, the existing control system was employed to give thermostat-driven on-off control with pause-pulse of the fuel auger. The original fan control was used to switch the new primary air fan via a relay, its speed being manually set using a potentiometer. This permitted the development of a stable

Lambda control loop for control of flue O₂ content (ie excess air) by means of speed control of the secondary air fan.

A load control strategy was then developed, yielding a 0-100% load signal. The next stage was to scale the load signal into a flame temperature setpoint, and then to use this to drive the combustion management system.

The final stage was to develop cross linkages between the control loops and to fine-tune their operation. The linkages are necessary to pre-empt large swings which can exceed the capacity of downstream control loops.

The prototype unit was successfully tested to ensure:

- general ease of operation in terms of reliability and lack of manual intervention required
- good combustion conditions
- good control
- turndown potential
- resistance to burnback.

The complete system was tested to ensure its suitability for the intended duty. Further modifications were made as required until fully satisfactory performance was obtained.



Figure 1 Boiler, and general view of test rig

CONCLUSIONS

The following objectives of the project were achieved:

- To separate primary and secondary air control and distribution.
- To use primary air preheating, to permit operation on wetter fuel.
- To improve the controls of the system ((feedback control from flue temperature and/or Lambda to fuel feed/air supply).

Spot efficiencies were raised from c.70% to c. 80% owing mainly to better combustion air control, and consequent reduction in excess air levels. The great reduction in slumbering time resulting from modulating control will result in seasonal efficiencies of over 70%.

The wet wood performance appears to have been improved. Difficulty in obtaining samples of the desired moisture content means it has not yet been possible to quantify, however, extended operation will verify this. It does appear possible to achieve 75% output at 40% mc.

A cost effective single-phase option was achieved. The use of an inverter as standard facilitates a single-phase option. This unit operated happily from a 13A socket throughout the trial.

POTENTIAL FOR FUTURE DEVELOPMENT

Further work that could advantageously be carried out is:

- Direct control of flame front.
- Increase of grate area to facilitate char burnout without ejection.
- Development of self-managing control strategies with remote monitoring. These would accommodate malfunction, and continue reduced operation whilst indicating an 'amber' alarm. This would reduce the amount of total shutdowns, increasing system reliability. Examples would include self-tuning to reduced output on wet fuel, recovery from auger motor trips, and possible self-ignition. 'Red' alarms and shutdown would only occur if the controls could not cope. This

could be developed on the present set-up.

- Development of control package with Touch-Screen PC running Windows CE and *idiot-proof* interface. This is *essential* for third party sites.
- The development of a PLC based control system to further reduce the cost. This would require the development of an integrated control panel replacing the SCADA system, but the production cost would be further reduced.
- Investigation of the potential to retro-fit the modulating control package onto existing installations – not necessarily stoker burners – where it is felt that modulating control would be an advantage. There are a number of existing installations in the UK, which might sensibly be upgraded in this way.

TECHNICAL DEVELOPMENT OF A RETROFIT WOOD BURNER FOR COAL UNDER-FED STOKERS IN COUNTY DURHAM AND SET UP OF DEMONSTRATION FACILITY

North Energy Associates Ltd

OBJECTIVES

- To reduce the cost of biomass heating plant.
- To develop a prototype low-cost conversion of solid fuel under-fed stoker boilers to burn wood at minimum cost.
- To provide a demonstration facility for wood-fired heating.
- To stimulate a business opportunity for marketing a coal-to-wood conversion.
- To utilise low-cost chipped waste wood arisings as fuel, thus saving the material from landfill.

SUMMARY

Durham County Council is keen to convert solid-fuel boilers to wood burning (in order to improve the emissions from boilers and to reduce CO₂). Some of the coal boilers are only 12-15 years old and not due for replacement for many years. Waste wood dust is available from a nearby recycling centre; the council wished to generate a use for this wood dust to avoid its disposal to landfill. At the start of the project, experiments were ongoing to manufacture wood pellets from the dust. An inexpensive way of converting the boilers to burn the

wood pellets was being sought, with low cost being more important than getting maximum efficiency out of the boilers.

Two schools were selected for the initial development work on the boilers:

- Ferryhill Comprehensive School, which is heated by three welded steel boilers (mainly manufactured by Hartley and Sugden with James Scott stokers).
- Durham Trinity Special School - Bek site (also known as Trouts Lane), which is heated by three cast iron sectional boilers (Beeston Robin Hood boilers with Riley Direkto stokers).

Work was undertaken on the following:

- The boilers and their air supply
- The fuel feed systems
- The fuel storage bunkers
- The fuel delivery arrangements
- The wood pellet fuel and its size and type.

The project demonstrated successfully that it is possible to fire some types of under-fed coal boilers with 8mm diameter wood pellets (with minor modifications to the combustion system) at a moderate cost with no loss in efficiency.

COST

The total cost of this project was £61,505, with the Department of Trade and Industry (DTI) contributing £28,891 and County Durham Environmental Trust and North Energy Associates the balance.

DURATION

22 months –July 2000 to April 2002

BACKGROUND

Durham County Council is keen to convert as many of their solid-fuel boilers as possible to wood burning (for environmental reasons). Some of the coal boilers are just 12-15 years old and not due for replacement for many years. The boilers in secondary schools, which are in groups of up to four, are normally oversized for the task. Budgets for boiler replacements are very limited, and an inexpensive way of converting the boilers is being sought (with low cost being more important than getting maximum efficiency out of the boilers).

A previous project to research fuel supply (Warmth from Waste Wood – fuel research, NEA, July 2000) funded by CDent, found that wood processing was taking place to provide woodchips for Egger, the local particle board factory (at a plant known as Joint Stocks Recycling Centre located near Coxhoe in County Durham). The dusty sawdust residue of this process was without a use and had to be landfilled for disposal. This earlier project found that it was possible to make a British BioGen Grade A pellet from the wood residues (provided that careful sorting of the waste wood took place). The pellets offered a good opportunity as fuel for coal boilers and were easier to

handle and more consistent than woodchips. Using pellets would help to keep conversion costs down (as the existing storage bunkers could be used with few modifications and the feed system was more likely to be able to handle pellets than woodchips).

THE WORK PROGRAMME

North Energy Associates carried out initial desk research and enquiries to find out if anyone in the industry had tried to burn wood pellets of this type in coal boilers. Some anecdotal evidence was offered that pellet burning had been tried but did not work very well, would seriously down-rate the boiler and would give emissions problems, but there were no written records of any trials. No published information could be found on burning pellets in coal boilers of the types commonly in use in County Durham.

The main aim was to find a solution at minimum cost. The process adopted was to start simple, test options and get more complicated only if needed. The BATNEEC principle was applied; the optimal solution was not necessarily sought if a reasonable solution could be achieved at lower cost. The team was always asking themselves whether or not the cost of improvement justified the cost. In essence, the process was one of trial and error.

It was expected that the different combinations of boilers and stokers would require different modifications to make them burn wood pellets satisfactorily. In the event, it turned out that development work had to be done on the following areas:

- The fuel feed systems
- The boilers and their air supply

- The storage bunkers
- The fuel delivery arrangements
- The wood pellet fuel and its size and type.

The following summary briefly describes trials. Adjustments, modifications and tests were carried out over an eighteen-month period in the two Durham schools. At Ferryhill, a chapter of unforeseen events prevented the continuous pellet firing of the boiler over the winter of 2001/2, but at Durham Trinity the boiler burned pellets for most of the autumn and winter terms. At Ferryhill pellets were burned for a number of shorter periods (up to two weeks long).

Both types of system required the addition of an anti-burnback device to prevent the fire burning back down the feed-pipe to the bunker. These were off-the-peg systems. An electrical anti burnback device was installed at Ferryhill (using a heat stat on the feed tube, connected to a valve controlling a supply of water from the pressurisation tank in the boilerhouse). At Durham Trinity, a similar heat stat simply opens a specialist valve (supplied by Danfoss), which dowses the feed pipe with water from a newly installed water tank nearby.

The modifications eventually installed in order to obtain satisfactory combustion at the two schools were in summary:

1. Boilers – adjustments to air supply systems and extension of over-fire air supply systems (with 2m long ducts for the Hartley and Sugden boiler).
2. Fuel feed – addition of anti-burnback device, addition of kindle clock to controls, adjustments to fuel-feed rate

3. Fuel Storage – addition of steel profiling to bunker sides (to direct pellets onto screw), minor adaptations to fuel delivery pipes, pressure release vent for air from bunker during delivery and draught proofing of bunker.
4. Fuel delivery – trials on various types of delivery wagon, and design and manufacture of adapter (to join feed pipe of pneumatic animal feed delivery wagon with feed point on bunker).
5. Wood pellet fuel – extensive development work on pellet quality, wood sourcing and sorting, delivery, dust extraction and pellet manufacture.

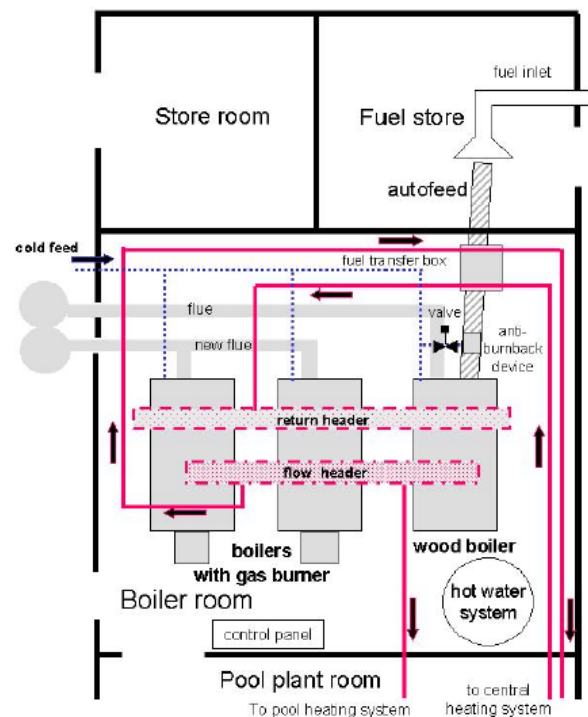


Figure. 1 The Ferryhill boilerhouse showing modifications

RESULTS

The result of modifications was that the boilers at both schools were able to burn 8mm diameter pellets (5-25mm in length) satisfactorily (with emissions that were comparable with purpose designed wood boilers). The boiler

efficiency was maintained at around 75%. The boilers are down-rated by roughly 50% (due to the lower calorific value of the fuel, which is about 16.5GJ/tonne, net).

Combustion efficiencies have been good, at 69-74%, at Durham Trinity (compared to 48-58% when using coal at the same site) and 75-88% at Ferryhill. Although taking a little longer when heating from cold, the boilers have been able to reach similar temperatures to those of the coal boilers. Maintaining temperatures has been no problem.

The total capital cost of conversion of one boiler and its storage bunker is approximately £1,500-£5,000 (depending on the amount of refurbishment needed to the system and whether or not the bunker needs to be modified to persuade the pellets to flow onto the bunker feedscrew).

Indications are that the operating costs of coal boilers converted to wood pellets (at prices being paid by Durham County Council in 2002) are slightly more expensive (under 3%) than the running costs of the coal boilers.

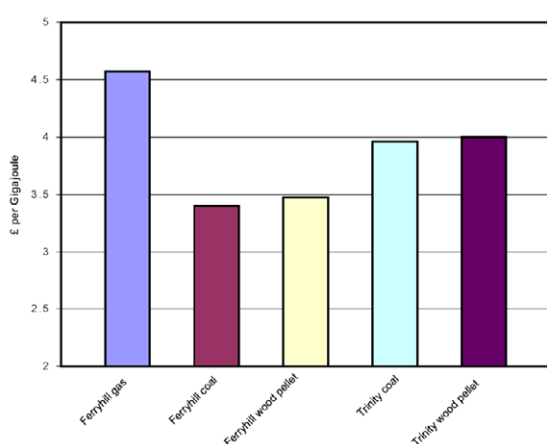


Figure.2 Comparison of costs for coal and wood pellet

Some savings occur that help to alleviate this increase in cost. Reduced wear and tear on heat plant means that

the school benefits from lower maintenance costs; less ash means lower disposal costs; and a reduction in caretaker time in operating the boiler plant frees the caretaker to do other work in the school. These advantages compensate for the slightly higher cost of fuel. The environmental benefits are also significant. Sulphur and CO₂ emissions are avoided by displacing coal, and tonnes of woody waste material is saved from being landfilled. Added to this is a huge reduction in transport fuel emissions, by bringing heating fuel from within County Durham (Trinity eight miles, Ferryhill four miles) rather than importing coal from Chile.

CONCLUSIONS

- The project has demonstrated that it is possible to fire some types of underfed coal boilers with 8mm diameter wood pellets with minor modifications to the combustion system (which involves moderate cost and no loss in efficiency).
- The boilers are down-rated by up to 40% (due to the lower calorific value of the fuel), but this is not a problem for sites where the boiler capacity exceeds the heat demanded (as is common in schools and public buildings).
- Every coal installation is slightly different, and it will be necessary to modify each on a case-by-case basis. It will not be possible to market a simple 'conversion kit' but to provide a conversion service with specialist engineers.
- An anti-burnback device and kindling controls are necessary to run the system safely.

- Conversions must include work to the fuel store and fuel handling systems, as well as to the boiler itself.
- To ensure long life, for most conversions it will be necessary to refurbish (or even replace) the stoker system (in addition to converting the boiler).
- The availability of high quality pellets is essential to the success of boiler conversions and the local supplier's delivery system needs to fit the delivery arrangements at the premises concerned.
- Success in running a solid-fuel heating system depends on having an interested and committed caretaker.
- The cost of heating with pellets is close to the cost of gas, but is up to 2% more expensive than coal bought in bulk (April 2002).
- If planning projects involves local authorities, allow three times as long as expected!
- The success of this project has furthered the desire of Durham County Council to phase out the use of coal. It has enabled the Council to start a programme of boiler conversions, which it plans to continue in order to convert its solid-fuel school boilers to wood pellet firing. If the price differential between gas and wood pellets continues to grow, the Council may even re-convert some converted gas boilers back to wood pellets.

POTENTIAL FOR FUTURE DEVELOPMENT

- Further work on other combinations of stoker and boiler systems would be useful.
- Restoring a boiler system that has been converted to gas to pellet firing would be desirable in order to assess practicality and costs.
- Further detailed emission testing is desirable to establish the levels of emissions not tested in the latter parts of this project. Testing for dioxins is desirable (as the early tests carried out during this project did reveal some dioxin in the flue gases). Work needs to be done to examine what is emitted to the atmosphere and what is deposited with the particulates in the flue.