Quarterly Progress Report, November 2003 – January 2004

The Use of Small Modular Biopower for Energy Production From Forest Fuel Reduction Activities

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Introduction

National Forest System lands; other Federal lands, and private lands need to be thinned to reduce the levels of fuels now posing risks to communities and adjacent lands. As part of the National Fire Plan, the Forest Service is providing opportunities to rural communities and businesses to diversify and expand their economies by turning wood into energy.

At the same time, the Department of Energy through the National Renewable Energy Laboratory is working on new technologies that produce distributed power (generation of power at or near points of consumption with or without connection to the existing power grid). These technologies include the use of small, modular biomass systems that produce less than 5 MW of electricity using biomass.

These two efforts merge in the realization that the Forest Service is interested in technologies that use forest biomass to produce energy and that DOE/NREL is interested in demonstrating this technology. Therefore, DOE/NREL and USDA Forest Service, Forest Products Laboratory have entered into a cooperative project aimed at demonstrating the use of small-scale modular biopower units to produce electricity using wood chips. The project involves the following activities:

- Preliminary feasibility and analysis of energy requirements and potential energy offsets using small-scale modular biopower units for 10 to 20 rural communities or businesses.
- Design and construction of a small modular biopower demonstration unit targeting 15-25 kilowatt (kW) peak power.
- Demonstration and evaluation of units in 6 communities/groups for a period up to 2 years per community/group. Communities/groups will be selected from the initial preliminary feasibility analysis.
- Final report and recommendations for improvements.

Background

Department of Energy

The Department of Energy (DOE), through the National Renewable Energy Laboratory (NREL) has instituted a program to develop technologies aimed at small modular biopower generation. Their small, modular biomass work focuses on demonstrating the economic and technical viability of advanced biomass conversion systems with capacities less than 5 MW_e.

Phase 1 of the DOE/NREL program focuses on market assessment, resource assessment, preliminary system design, assessment of relevant environmental and safety considerations, financial and cost evaluation, and preliminary business plan and commercialization strategy.

Phase 2a focuses on developing and testing the performance of a prototype small-scale biopower system, completing a detailed business plan and establishing strategic partnerships.

Phase 2b focuses on developing and demonstrating an integrated small-scale biopower system with operation and performance characteristics required to successfully compete

in the target market. This includes establishing the automated nature of feeding and operating the system, operating the system to establish operations and maintenance cost projections, measuring detailed emissions, and certifying the system performance.

USDA Forest Service, Forest Products Laboratory

Wood energy in the form of thermal, electrical or chemical energy is one potential use of forest residue and non-merchantable material. In its simplest form, wood energy is using a fireplace, stove, furnace or boiler to produce heat. The scale of operation ranges from individual homes, to buildings and facilities such as schools, offices and hospitals, up to providing heat and electricity in large industrial wood processing plants. Currently, most of the wood energy activity is associated with industrial wood processing facilities, such as sawmills and pulp and paper manufacturers. Wood by-products, such as bark, sawdust and pulp liquors, are burned to create heat and/or electricity for the facilities. In some cases, excess electricity is sold to local power grids.

The FPL has been focusing on improving forest management and wood utilization options by integrating the use of small-diameter material for bioenergy and other bio-based products. In most cases other bio-based products are even higher valued than use of wood for energy. But there will always be residues and non-merchantable material that would be suitable for energy production.

Nationwide, a major focus of the FPL Wood Energy Program is to assist rural communities to develop local facilities to process wood into thermal and electrical energy. Based on preliminary response, interest is high in small, local projects that use the excess residues from thinning operations. Small-scale modular units, such as being worked on by DOE/NREL, are the types of units that are well suited to the small-scale application to produce thermal and electrical energy.

Approach

The small, modular biomass units being developed by DOE/NREL hold tremendous opportunities for both offsetting some of the local energy needs and using forest residues. However, this technology is still in the pre-commercial phase. Further evaluation is necessary to lower the cost of the technology and to gain a better understanding of the operation and maintenance of these pre-commercial units. At the same time, there needs to be additional market assessment to determine the potential market size for this technology.

Objectives

We will address some of these issues by conducting a demonstration program. The primary objectives of the demonstration program are:

- To evaluate the capability of a small, modular biopower unit to offset energy requirements for a single operation, such as a business, community center, school, or other local group.
- To evaluate the potential of wood chips as the fuel source.
- To determine operating and cost parameters.
- To demonstrate this technology to a wide variety of potential users.
- To recommend modifications and procedures for more efficient operation.

Procedures

The following activities are included in this demonstration program:

1. *Preliminary feasibility analysis*. The DOE/NREL/FPL and sub-contractor will visit 10 to 20 communities or businesses interested in this demonstration program to assess the feasibility of operating a small, modular unit to meet some of their localized electricity needs.
    a. The FPL will provide the list of potential communities interested, then working with the DOE/NREL/FPL and subcontractor the list will be narrowed down to about 15 to 20 communities to visit.
    b. A technical group will visit these communities and conduct a preliminary feasibility of the community/group serving as one of the demonstration sites
    c. Contractor/sub-contractor will provide written report on the pre-feasibility phase.
    d. FPL, DOE/NREL and subcontractor will then make a final determination of demonstration sites.
    e. FPL will coordinate demonstration timeframes with the communities/groups.
2. *Design of small, modular unit*. Based on the pre-feasibility study, a unit will be designed that meets the purposes of the selected demonstration sites.
3. *Fabrication of unit*. Unit will be constructed and pre-tested. Unit should be capable of using excess heat to dry wood chips and have an automated feeding system for the wood chips. Potential option might be recovery of waste heat for thermal heating. Units must address all potential safety hazards and have backup safety systems. Units will be maintained on a trailer, or skid pallets, that can be transported with a pick-up truck. Contractor/sub-contractor will train site hosts and FPL scientists on operation.
4. *Coordination.* After testing, FPL will be responsible for delivering demonstration equipment to test site. Contractor/subcontractor will be responsible for hooking up and testing. Data collection responsibility would fall to both host sites and contractor/sub-contractor. These details will be worked out later depending on availability.
5. *Demonstration.* Unit will be at the demonstration site for a period up to 1 year. If additional funding is available to FPL, we will coordinate one regional demonstration workshop to showcase operation at each demonstration site and arrange a program of tours.
6. *Site Reporting*. After each demonstration site, contractor and FPL will jointly write up report to cover both the operation, cost efficiencies and technology transfer aspects at each site.
7. *Project changes*. Modifications to the demonstration program (both technical and marketing aspects) may be made at various points in time.
8. *Final Report*. At end of demonstration program, FPL, DOE/NREL and contractor will jointly produce a final report.

Progress During Quarter

Efforts during this reporting period were focused on the following areas:

- Host site operations monitoring and site support activities
- Design and fabricate additional BioMax 15 for Southern California
- SMB design refinements
    - Gasifier control software improvements
    - Engine controls development

Site Operations

There have been a number of SMB operating issues that have surfaced as a result of the Host Site validation project. This is not unusual but rather an expected result of purpose of deploying these systems to private host users. Some common issues appear to be tied to ambient thermal conditions, both hot and cold. During really cold days the engine experiences more difficulty starting and going through the transition from propane to producer gas. Discussions with the engine/generator provider indicated that this is not uncommon and is one of the reasons they provide engine block (coolant) heaters with their systems. CPC has instructed each of the sites how to implement this heating configuration to improve cold weather starts.

Continuing problems with erratic readings of some temperature locations in the system appears to be related to the thermocouple input boards being located in an environment that was too hot. The solution to this problem will be to relocate the TC modules to a cooler location in the control panel.

Issues at specific sites are as follows:

Walden

The heat exchanger in this unit developed leaks again. This was the second failure of the heat exchanger integrity at Walden. The leak occurred as a result of the tube sheet welds breaking due to thermal expansion. This is a common failure mode for heat exchangers and is exacerbated in this situation because of the high temperature difference experienced at the producer gas entrance in addition to the two-pass design. CPC has replaced this exchanger with one having a heavier gage tube sheet. This design issue will continue to be monitored closely.

New gasifier control codes were provided to Walden that appear to improve the systems ability to handle fuel with higher moisture contents. The dryer is effectively removing moisture from the feed during transport from the day bin to the gasifier entrance. Wood chips can be consistently reduced in moisture content from 25% to the low teens before introduction to the gasifier. However, during the drying operation hot air from the heat exchanger will entrain wood dust with exhaust air creating a local environmental issue. A simple cyclone in the dryer exhaust line would be an easy fix to this problem.

During January the cal-rod (resistance heater) used to “light off” the char bed during system startup was found have burned out. This could have occurred if the operator went through the startup cycle again while the char bed was already hot. To prevent this from happening in the future the operating code was modified to check the gasifier grate temperature before allowing the cal-rod to be energized.

Recent inspections of the gasifier internals have revealed significant amounts of tramp material (stones, nuts, bolts, etc.) deposited on or under the grate. While not a design issue with the SMB itself, it does demonstrate the importance of managing the fuel supply logistics to prevent these materials form entering the system.

A total of 152 hour of operation has been logged on the Walden unit by the end of January.

Ruidoso

The SBS Wood Shavings site saw diminished use in December because the vibrator used to automatically screen the chips being fed to the unit was continuing to malfunction. It was subsequently discovered that the reason was probably due to overloading chips to the screen. In early January the employee who normally operated the SMB left the company. SBS Shavings is a startup company that continues to struggle to make ends meet just to serve and expand its existing customer base. Although well intentioned in wanting to support the SMB validation project, the owners simply do not have adequate manpower or resources to keep their business going and devote adequate time to daily operation of the SMB. This also presents a problem for the remainder of this project since there are only a few months remaining and not enough funding resources left to retrain additional operators or move the unit to a different location.

A total of 105 hours of operation has been logged on the unit at SBS Wood Shavings since it began regular operation in early October.

Zuni Furniture Enterprise

The local tribal environmental office initially only gave provisional approval to operate the system on a regular basis. They permitted operation when CPC was training the local operators but were still investigating the need for an Air Quality Permit even though one was not required for the unit deployed to SBS Wood Shavings (also in New Mexico). NREL staff was involved in helping the tribal environmental office make this decision. A complete NEPA package was provided to the environmental office in late September and in Early November a letter report describing the results of emissions analysis conducted on the SMB in June 03. Even though the emission results met the stringent requirements of the California Air Resources Board the local tribal EPA was still undecided about the need for a permit. Apparently this issue has been resolved and the system will be permitted to run on a regular basis without the permit.

Some minor operating difficulties were experienced in January when the seal at the base of the gasifier was not set properly and an air leak caused erratic engine operation. On another occasion the system was not shut down properly and the char bed was converted to ash so additional char had to be produced separately to establish the char bed. As with hardware technical issues, these are the types of lessons learned intended to come out of the validation project.

Additional BioMax 15 for Southern California

In December staff from CPC, NREL, and the Forest Products Lab traveled to San Bernardino to discuss potential host sites for deployment of a BioMax system in U.S. Forest Service Region 5. A number of potential sites were discussed prior to visits to the actual locations and some were eliminated due to logistics or programmatic priorities. Three sites were visited in the Big Bear Lake area but the team quickly identified the U.S. Forest Service Discovery Center as the most appropriate to house a SMB. It was also determined that a 50 kW unit, similar to the one to be

designed and deployed to Mt Shasta (supported by the California Energy Commission), would be the most appropriate system to deploy. This system size will be able to provide all of the building heating and power needs while also having additional power that could be dispatched to the grid. In addition to the 50 kW unit for the Big Bear Discovery Center a smaller 15 kW BioMax was requested to be fabricated and delivered to the Forest Service for demonstration at the U.S. Forest Service National Leadership Conference to be held at Arrowhead Lake at the end of February. Parts for this unit have been ordered and fabrication is underway.

SMB Operational Control Design Refinements

Obtaining good operational control with the in house designed microprocessor control system continues to be a challenge. The major technical issues relate to engine control and to a lesser degree stable long-term gasifier operation. In November an in depth evaluation of the control problems was undertaken with the purpose of identifying the sources of the problems and developing potential solutions.

Issues with the gasifier operation primarily related to maintaining a stable flame front and a relatively stable pressure drop through the bed. Both of these issues are strongly influenced by the control of bed vibration. This control parameter needs to strike a balance between providing adequate vibration to insure the gasifier bed does not develop gas channeling while minimizing the time, frequency, and power applied to prevent excessive char removal from the bed. A mechanism to change these variables automatically via the control system is currently being investigated. Other major revisions to the control code have resulted in the ability to maintain longer char bed with a corresponding higher flame front and the ability to tolerate higher levels of moisture in the feed. In addition the new algorithms have resulted in significant reductions in the time required for the gasifier to achieve steady state operations from a cold startup.

The continuing problems with the engine control are occasional surging and making a smooth transition from operating on propane to operation on producer gas. This is a difficult challenge because of the significant differences in the chemistry of these two fuels. Propane is a hydrocarbon having a relatively high heating value whereas producer gas has a low heating value and is comprised of two different gases having widely varying flame propagation values. The control program is required to adjust the air valve to maintain proper combustion air as it tries to reduce the propane input as producer gas quality rises. The control feedback loop incorporates an oxygen value in the exhaust gas as one of the primary parameters to control on during this process. The evaluation conducted in November identified the use of a narrow band O_2 sensor as a potential source of the difficulty. A more expensive wide band sensor has been procured and installed in the system. In addition to the wide band O_2 sensor an engine crank sensor has also been installed to also link this important variable to the control code. New codes have been written for these two new sensors and testing will begin after de-bugging has been completed.

Outreach Activities

John Scahill was invited to speak at the Bioenergy and Wood Products conference held in Denver on January 20-22. This joint conference was sponsored by the Department of Interior, the Department of Agriculture, and the Department of Energy. The title of his presentation was “Biomass to Energy: present commercial strategies and future options”.

Contractual Activities

The CPC Monthly Progress Reports are provided as Attachment A.
Attachment B is the Subcontract Financial Status report.

Planned Work for the Next Quarter

All three sites will continue to be monitored throughout the critical initial phase of operation by the on site operators. CPC will be ready to provide any assistance that may be required to support the sites.

The new engine control code will be tested with the wide band O_2 and engine crank sensors installed. The gasifier operation using the automated vibration control will also be tested.

Complete fabrication of the additional 15 kW BioMax and conduct initial lab testing before delivery to San Bernardino at the end of February.

Attachment A: CPC Monthly Status Reports

November 2003 Monthly Technical Status Report

Phase II Small Modular Biomass Power
Subcontract No. ZDH-9-29047-01 [Mod. 6]

The following is a summary of the progress for the month of November 2003, as related to the major tasks noted in the subcontract.

Summary

Systems are being operated independently at Ruidoso, Walden and Zuni. Three separate R&D efforts are underway in the areas of engine controls, gasifier controls and software overhaul to try to improve operating availability and stability. A new plan has been implemented for CPC engineers to contact the sites every day due to ongoing difficulties in getting timely feedback. A set of instructions for site operators on data collection and reporting has been finalized.

MMBH Progress

On hold, pending success in ongoing engine control R&D effort.

Walden Site

Walden had 5 days of continuous runs the first week of the month and then was shut down for cleaning prior to a demonstration on Monday the 10th. The run on the 10th was unsuccessful, as was the run on the following day. We believe something associated with the cleaning upset the normal system parameters, possibly an air leak. The system was dormant for the next three weeks due to the Thanksgiving break.

Ruidoso Site

Rick Bergman and Joe Lamont operated the Ruidoso BioMax on Nov. 3 and Nov. 4.
Joe Lamont and Jim Diebold operated the unit on Nov. 5. Glenn Barrow and Jim Diebold operated the unit on Nov. 6, with assistance in starting from Joe. Glenn Barrow and Jim Diebold operated the unit on Nov. 7. After Jim left the site, Joe told me that he operated the unit once for some visitors, during November. The system was not run during the Thanksgiving break. Communications with the operator at the Walden site have been difficulty due to conflicting academic commitments

Zuni Site

The site at Zuni was handed over on November 4th. After three runs with CPC in attendance, the system was run another several times for operator practice. The site was not allowed to operate according to local EPA regulations without the addition of a catalytic muffler to reduce NOx emissions. A CPC engineer drafted a quick study of available catalytic converters and their integration into the SMB system and sent a suitable retrofit package to Zuni in late November. The system was returned to operation beginning the first week of December.

Engine Controls Testing Program

After a year of relatively successful engine operations at CPC began to see a number of problems related to engine control when the SMB systems were deployed in the field. Operation on propane was no longer a given and transitions from propane were difficult, time consuming and unreliable. We also found that control valves needed to be tuned to individual site conditions and even then would operate inconsistently based on thermal conditions. Most of the problems at the sites to date have been related to engine startup and transitions. An in depth design review paper was drafted and circulated by Mike Fields on the history of CPC's engine control strategies and hardware configurations to date. A team meeting was held on November 12th to brainstorm these problems and possible solutions.

Minutes from Meeting:

Discussion started with blower systems. There are three basic reasons to add a blower to the system:
To boost the engine inlet pressure above atmospheric to match the propane power levels of the generator while running on producer gas.
Cost savings/ reliability - buy a small blower, small motor (no controller) and flare to start the GPM. Start the unit on producer gas, do minimal engine modification and engine controls (producer gas controls only)
To create a unit that doesn't require any fossil fuels for startup. The system would require a battery/inverter system capable of sustaining the electrical load while the engine starts.

Currently warm-up takes 1 hour (engine start to completion of transition to producer gas). The long warm-up consumes a lot of propane. One of the problems is the low GPM flow rate (18 SCMH) reduces the amount of heat transfer from the band heater in the filter. Mike proposed looking at engine exhaust as a heat source for preheating the system. Jim pointed out that the added electrical load of the existing pre-heaters barely affects the consumption of propane during startup (no load consumption Vs partial load consumption). It was proposed to put a higher load on the system to increase the GPM flow rate during the pre-heat phase of startup. The match between the filter band-heater and the heat exchanger pre-heaters would need to be checked and optimized.

We discussed the vaporizer and the suspected problems of the vaporizer during cold startup with output pressure to the injector. Some vaporizers are configured for cold weather and all can accept an electrical heater attachment for cold weather operation. The first test would be to install a pressure gauge into the injector line and establish a pressure/temperature curve. The first configuration change proposed for testing was eliminating the vaporizer altogether and using vapor feed propane systems. The suspected problem of adequate heating and variable pressures would be eliminated, and there would be a cost savings from not having to buy the vaporizer. The site would be required to use propane storage tanks sufficiently large enough to avoid tank freezing due to the rate of phase change inside the tank.

We also talked briefly about triggering the propane injector off the engine ignition as discussed in Mike's paper. This was adopted as the second configuration proposed for testing.

We discussed O_2 sensor problems, both during producer gas operation and during transitions. Mike had begun to investigate wide-band O_2 sensors. The wide-band sensors showed promise for allowing tighter control of the stoichiometry. The tighter control could eliminate some of the difficulties with the stoichiometry that we have experienced using narrow-band O_2 sensors. This was adopted as the third configuration proposed for testing.

We discussed the benefits of measuring inlet gas temperatures at the engine for air density corrections and accurate mapping of fuel mixture control. This was adopted as the fourth configuration proposed for testing.

Given the variability of existing control valves, which must be individually tuned for each site, as well as the uncertainty about their stability we initially discussed a test plan to characterize these valves. However, we decided that positive control or position feedback would be necessary for accurate mapping of mixture control set points. Mike W. preferred positive control to positive feedback and Mike F. was familiar with rugged servo control mechanisms, so we decided to pursue accurate and repeatable position control retrofits of the existing combustion and producer gas valves. This was adopted as the fifth configuration proposed for testing.

We also elected to put a flow meter on the inlet to the engine in or to gather data about volumetric flow efficiency for future mixture calculations.

The discussions touched on bumping engine compression to improve the engine's ability to combust non-stoichiometric gases. We also considered using gasoline in lieu of propane as a starter and backup fuel. Gasoline would enable a much wider selection of injectors and would probably be a more universally available fuel. If we decided to increase engine compression, the gasoline would be more restrictive than propane due to pre-ignition problems. Gasoline would also require ignition-timing control whereas propane and producer gas presently run well using fixed timing settings.

King brought up the idea of pumping and storing small amounts of producer gas for subsequent startups, thus eliminating the need for propane and eliminating some of the combustion transition management problems.

Dusty brought up the methane sensor, which he learned requires 10% oxygen in the gas being measured. We discussed a slipstream approach to adding air for methane measurement and adding the mix back into the producer gases.

Trevor raised the concern that we consider emissions quality in our continuing search for improvements to engine combustion control. Retaining control of a retrofitted propane injector allows us to retain combustion control for optimum stoichiometry and lowest emissions, unlike the stock setup.

In general, we decided to tackle the 5 avenues of investigation listed above initially to try to improve the operational flexibility and stability of the existing system design and components. These will be pursued in parallel and as aggressively as possible with email updates to the team. We will continue to consider alternative strategies such as flares, blowers, alternative fuels, component substitutions, engine modifications and alternative heating and startup power storage strategies.

CPC has currently committed to a test plan involving 400 man hours of engineering time to investigate strategies for improving engine startup and run stability on both propane and producer gas. Following the design meeting, a test plan was drafted and testing during the last two weeks of November has focused on characterizing the existing system performance and stability under different operating conditions. Preliminary results will be reported in next months report.

Gasifier Controls Testing Program

CPC has also currently committed to a test plan involving 400 man hours of engineering time to investigate strategies for improving gasifier stability and automated operation. As we have gained experience at the sites we are finding wide variations in fuel quality and moisture content, as well as varying environmental conditions, have caused various problems with gasifier operation, including flame front instability and high char yields. Since the beginning of November, we have made extensive revisions to the gasifier control algorithms and we have automated control parameters such as grate vibration interval and duration that were previously set manually for a particular set of fuel and run conditions. We will continue testing until we have achieved our goals

of fully automated and stable operation under all site conditions. The first gasifier controls upgrade is expected to be implemented in early December.

Controls Software Overhaul

We have been aware for some time of structural deficiencies in our VB software code. Some of these are problems inherent in the way the code was originally crafted, while others are the result of poorly implemented patches over time. Finally, day to day operation of the system has revealed software code deficiencies that needed to be addressed. At times, the structural problems have caused the software to 'get lost' or 'hung up' due to unrelated communications delays or faults and caused system shutdowns. One typical problem is that the variable initialization in various run states depends on the transition from the previous state. This meant that if the operator, out of normal sequence, manually forced the run state then the variables would not be properly initialized. Without knowing this, the operator would think the system was operating normally in a particular mode while the system was, in fact, operating with incorrect settings.

In November, CPC hired a consultant to draft new software code for the fluidized bed system being completed for a separate poultry litter gasification project. The resulting code had a number of features that overcame problems with the existing 15kW SMB code, so we have decided to rebuild the 15kW code on the foundation created by the consultant for the poultry litter project. This code will be finalized and tested in the first two weeks of December and once verified, distributed to the sites as a software upgrade.

Activities for the Next Reporting Period

All three sites will continue to be monitored on a daily basis until operations are routine and relatively stable. We will continue to be ready to provide any assistance that may be required to support the sites.

Ongoing R&D will continue in the areas of engine controls and gasifier controls. As improvements are achieved and confirmed in testing we will upgrade the sites as quickly as possible. Software overhaul will be completed, tested and distributed in December.

December 2003 Monthly Technical Status Report

Phase II Small Modular Biomass Power
Subcontract No. ZDH-9-29047-01 [Mod. 6]

The following is a summary of the progress for the month of December 2003, as related to the major tasks noted in the subcontract.

Summary

Systems are being operated independently at Ruidoso, Walden and Zuni. A set of instructions for site operators on data collection and reporting has been finalized and sent to the field test sites for implementation. This will provide a bi-weekly reporting

system on every day of SMB operation, including operating time, approximate kW_e generated, feed moisture content, problems encountered, and problems solved, etc.

Three separate R&D efforts are underway at CPC in the areas of engine controls, gasifier controls and software overhaul to try to improve operating availability and stability. Improvements in the gasifier control have resulted in shorter startup times and "hands-off" operation of the system in Run Mode 4 at CPC and at Walden. However, Walden is still having problems with transition, which we are addressing. The software overhaul has been written and is ready for shakedown testing.

MMBH Progress

On hold, pending success in ongoing engine control R&D effort.

SMB Field Test Sites

New Personnel

The first of December, Don Wright started work at CPC as the official SMB Field Engineer. Don has a BSME degree from John Brown University in Arizona and a MSME from Colorado State University. He has ten years experience in engineering design and test equipment development and testing. He also worked with Dr. Bryan Wilson while at CSU and has a solid working knowledge of engine systems. He spent a week at Walden learning first hand about the SMB and working with Mike Walker of CPC and Phil Anderson of North Park. His CPC training will include working on the assembly of the next SMB to be delivered to San Bernardino, CA.

Data Collection and Communication at the Field Test Sites

To identify and achieve performance improvements in areas important to commercialization, procedures for documentation of information about the BioMax systems has been sent to all field test sites and discussed with them. They have agreed to fill out a Run Log form after each run that documents the ambient conditions, the run time, fuel, moisture content, electrical load levels, start up time, run problems, health and safety issues, propane consumption, wood consumption, maintenance performed, repairs, etc. These Run Logs and the routine data files are to be burned onto a CD and sent every two weeks to CPC for review.

Walden Site

Early in December, Phil Anderson reported that they had a large leak in the heat exchanger, problems starting the engine on cold mornings, trouble passing through the transition from propane to producer gas, long startup times, a bad theromocouple module, and intermittent pressure readings. A team of three engineers (Mike Walker, Don Wright, and Trevor Smith) were sent to Walden.

Trevor swapped out the leaky heat exchanger with a relatively new one and brought the leaky one back to CPC for examination and repair. The other two engineers stayed in Walden for the rest of the week to install the latest control software, to trouble shoot the problems experienced in starting and in transition, and to see how the new gasifier control program works in Walden.

At CPC, the Walden heat exchanger was found to have failed in the welds joining the tubes to the tube sheet at the hot entrance. This heat exchanger has been repaired and now has enhanced clearances to better allow thermal expansion. The repaired heat exchanger will be tested soon at CPC.

It was found that the engine coolant heater was only powered during engine operation. Discussions with the Generac representative in Denver revealed that it was very easy to wire the coolant heater so it could be plugged into the grid, which was done. This preheats the engine block and the propane vaporizer for easier cold morning starts, as well as, keeping the battery fully charged.

A high pressure-drop was observed across the filter. After vacuuming the filter did not appear to improve the situation, the filter bag was replaced. The new filter bag has a low pressure drop during operation.

The new control code with higher air flow rates in Warmup Mode 2, contribute to a reduction in warm up time of about half an hour.

The engine still has trouble in making the transition from propane to producer gas without stalling. This requires that the engine be manually re-started. The new gasifier control code appears to be working very well in Run Mode 4, with several long runs at Walden being made with no operator intervention.

The dryer/feeder was drying the feed from 23% to 10% moisture. In some of the runs, the hot air duct was disconnected from the dryer, with the gasifier able to operate with the higher moisture content of the feed. This confirms the experience at Zuni in early November, i.e., the recent revisions to the gasifier control code allow a wider tolerance of moisture in the feed. Ducting the hot air through the dryer dries the feed, but it releases fines into the dryer exhaust air.

The thermocouple module in question was found to be faulty and was replaced. A Drager CO monitor was left at Walden, so that they can more accurately measure the CO levels in the vicinity of the SMB. This high quality CO monitor numerically indicates CO levels between 0 and 400 ppm, with an audible alarms at 35 ppm and 100 ppm.

In December, the SMB was operated seven days (December 9, 10, 11, 12, 15, 18, and 19). School holidays precluded operation at the high school during the last two weeks of December.

Ruidoso Site

The malfunction of the vibrator used to sieve the wood chips was responsible for the unit at SBS Wood Shavings to be idle in early December. We first assumed that the wrong type of fuse was being used, but the fuses we sent to them were also summarily blown. We then suspected that the old wire that SBS used to install the vibrator on their modified sieve was faulty, so we waited for them to re-wire the vibrator with new wire. When this failed to remedy the problem, we ordered a new vibrator to be sent directly to them. The new vibrator has been installed and successfully used to sieve wood chips with their modified screening system. We have examined the bad vibrator and found that it had a high amperage draw if it was restrained from moving, such as might be the case if the screen was heavily loaded.

During the warm up cycle in Mode 2 on December 19, they experienced a rapid temperature rise in the temperature of the air between the heat exchanger and the filter (FilterIn). This temperature exceeded 135°C, so the system went to the Emergency Shutdown Mode 6. The data were e:mailed to CPC for study. The temperature rise occurred just <u>before</u> the cal-rod was activated, when the FilterIn temperature had reached about 72°F. It had a finite rise rate, unlike the reading of an open thermocouple that suddenly jumps from its true temperature up to about 1100°C. This temperature reached a maximum of 151°C after about 2½ minutes, before the system was shut down. The cal-rod was activated for about a minute during this time, but

fortunately the gasifier did not light off. The cause of this temperature rise is unknown and is under investigation by Joe Lamont at SBS Wood Shavings, who will inspect the filter bag and the inside of the heat exchanger. However, the duct heater appeared to have the correct electrical resistance after the incident.

We have sent a Drager CO monitor to SBS Wood Shavings, so that they can more accurately measure the local CO levels around the SMB. We have also sent them instructions for wiring the engine coolant heater so that it can be plugged into the grid for preheating the engine block and propane vaporizer on cold mornings.

The system was not operated over Christmas week.

Zuni Site

The SMB at the Zuni Furniture Enterprise (ZFE) was run once on December 3 for seven hours as a training exercise. During the last 30 minutes of this long run, the DryerIn temperature was becoming erratic. Prior to this run, aluminum foil was placed between the dryer and the thermocouple module for the DryerIn to act as a radiation shield. However, it is suspected that the thermocouple module was still overheating and causing the problem. They plan to better insulate this module prior to the next run.

The local EPA has ruled that ZFE qualifies as a small quantity generator, which allows them to store hazardous waste for up to 6 months prior to disposal. They have identified a hazardous waste hauler that will remove any hazardous waste they generate, as part of their hazardous waste plan. EPA is still reviewing whether or not ZFE needs an Air Quality Permit, although the New Mexico Environmental Department required one for the Ruidoso unit. It appears that the environmental requirements are close to completion.

ZFE decided that before they service the unit prior to the next run that they wanted to have a better CO monitor to ensure the safety of their employees. A Drager CO monitor was shipped to them for this purpose.

We have sent them detailed instructions on how to wire the engine coolant heater to make starting the engine easier on cold mornings.

ZFE is planning daily operation of the gasifier starting December 30.

Engine Controls Testing Program

We have found that the Generac engine's coolant heater can be easily wired into the battery charger and that both can be plugged into an electrical grid outlet. This provides a pre-heated engine and propane vaporizer that make the engine much easier to start on cold mornings. To reduce grid usage, an inexpensive timer can be used to turn on the battery charger/coolant heater an hour or so prior to starting the engine. Instructions on this simple modification have been sent to the three field locations.

The necessary parts for the use of a broadband oxygen sensor have arrived and are ready to be tested. The broadband oxygen sensor is expected to provide an improved control of air-to-fuel ratios than we have had in the past.

Gasifier Controls Testing Program

The gasifier controls have been modified to improve the ability of the SMB to function with: shorter startup times; a more stable, longer char bed; the use of vibration to primarily settle the

char bed (not to remove excess char) and to maintain a moderate gasifier pressure drop; and less operator intervention.

When the engine is first started, it pulls the residual producer gas out of the gasifier and gas clean up systems. This requires that the engine's combustion air valve be open, while the system purges itself of producer gas. We now operate the first five minutes with the producer gas valve partially closed and with the combustion air valve open as required.

To reduce the startup time, after the first five minutes we have completely closed the engine's combustion valve during the Mode 2 warm up. This increases the flow of air through the gasifier in Mode 2, which allows the thermostatically controlled filter drum heater to cycle-on more of the time. This results in a much faster warm up of the system.

The algorithm of the moderating blower that tempers the air going to the dryer has been better tuned to provide a more constant temperature in the hot air going to the dryer.

The control of the gasifier has been changed to automatically provide a more consistent location of the pyrolysis flame front high in the gasifier. This appears to result in the ability of the gasifier to tolerate higher moisture contents in the feed. This has required the addition of algorithms to automatically vary the char-air flow rate, the gasifier vibration interval, and the gasifier vibration duration. Previously, the gasifier-vibration variables were manually changed by the operator in response to changes in the gasifier pressure drop and in the temperatures. A minimum char-air flow rate is provided to assure that the residual tar vapors are cracked in the char bed. The grate temperature is maintained between upper and lower limits. The operator can override these control variables, if necessary to protect the equipment from damage.

In the last 4½-hour long run at CPC with the SMB, the gasifier control settings were successfully left unchanged, while the electrical load was changed from 9.7 kW_e to 11.3 kW_e, and finally to 14.7 kW_e and then back to 11.3 kW_e. Although the automatic control of the gasifier was judged by the operator to not require his intervention, a review of the data suggests that much tighter control is both desirable and possible. We will continue to improve the gasifier control algorithms to further improve the gasifier stability.

Controls Software Overhaul

This new SMB control code has been written to eliminate the source of observed problems in the old code, but continues to use the control features that have evolved in the past several years of development. The new code has been structured to make it easier to install at the field test sites, using site specific variables. The new code has been completed and installed in the SMB at CPC. Shakedown tests of the new SMB control code will commence the last week in December.

Activities for the Next Reporting Period

All three sites will continue to be monitored on a daily basis until operations are routine and relatively stable. We will continue to be ready to provide any assistance that may be required to support the sites.

Ongoing R&D will continue in the areas of engine controls and gasifier controls. As improvements are achieved and confirmed in testing we will upgrade the sites as quickly as possible. Software overhaul will be completed, tested and distributed in January to the field test sites.

January 2004 Monthly Technical Status Report

Phase II Small Modular Biomass Power
Subcontract No. ZDH-9-29047-01 [Mod. 6]

The following is a summary of the progress for the month of January 2004, as related to the major tasks noted in the subcontract.

Summary

BioMax systems continue to be operated successfully at Walden and Zuni.

The person assigned as the operator of the BioMax system at SBS Wood Shavings in Ruidoso left the company, leaving the site inoperative. Since commissioning of the system, this is the second operator to receive training and then leave SBS Wood Shavings. CPC does not have funds to continue to provide training to new operators. CPC recommends that the BioMax system at Ruidoso be relocated. Relocation will require additional funds for system shipment, installation and on-site training. *Please see a further discussion of this issue at the end of this report.*

Separate R&D efforts in the areas of gasifier controls and software restructuring have been completed, resulting in significant improvements to operating availability and stability. Engine controls R&D is continuing.

MMBH R&D and testing has been reactivated in anticipation of deploying the MMBH system to the USFS Forest Products Laboratory Research Demonstration House in Madison, Wisconsin in early March.

CPC deployed a 15kW Biomax system to NREL in support of the technology demonstration tours being held in connection with the Bioenergy and Wood Products Conference held in Denver on January 20-22.

Controls Software Overhaul

Testing has been completed on new SMB control code that was rewritten to eliminate the source of observed problems in the old code. The new code has been structured to make it easier to install at the field test sites, using site-specific variables. It is designed specifically to facilitate manual transitions from one operating mode to another to allow rapid recovery by the operator in the event of a problem or unexpected shutdown. It also has a significantly upgraded user interface. This new code is currently being installed into the Zuni site.

Gasifier Controls Testing Program

Testing has also been completed on the gasifier controls. Changes made to the code have resulted in shorter startup times; a higher flame front; more stable, longer char bed; the ability to maintain moderate gasifier pressure drop over longer durations; the ability to operate automatically on a wider range of fuel moisture content; and less operator intervention. Gas quality, gas conditioning and power availability have not been affected by these changes. In addition to these changes affecting controllability, we are also investigating automating grate vibrator power levels in order to give us an additional control input to cope with rapid variations in feedstock moisture content. The power level of the gasifier vibrator has been varied by a manually turning a rheostat. We normally have not been changing this power setting during a run. However, the operator will manually change this power setting as a last resort, if the gasifier pressure drop is too high or the flame front is too high. If GTC1 exceeds 400°C, a yellow alert is

activated. This requires operator intervention to increase the vibrator power setting to avoid going to a controlled shutdown. We have found a way to automatically control the vibrator power level and will be implementing this at CPC. This will automate the last operator-adjusted variable. We are now in the process of determining how best to utilize this variable to vibrate the gasifier at the least severe power level to achieve sufficient vibration to settle the bed and to adequately control the pressure drop and the flame front in the gasifier bed.

Engine Controls Testing Program

The broadband oxygen sensor has been installed along with an engine crank sensor. A control algorithm has been written to take advantage of these new sensors for better propane/air management and engine control. Testing is in progress to debug these new sensors and control algorithm.

MMBH Progress

The MMBH system is currently undergoing several upgrades to support the deployment at the Forest Products laboratory. These include incorporating the existing operating algorithms onto a restructured software base that was developed for the Biomax 15 systems. Debug of the rewritten software code will be completed the last week of January. As improvements to the engine control system and control code become available these will also be implemented into the system. Currently the system is very stable and operating in daily charge cycles, but still having difficulty making it through the transition from propane to weak producer gas. When the system has achieved stability throughout the startup cycle, the system will be reconfigured to operate on wood chip vs wood pellet fuel. The higher variability of wood chip fuel, in terms of particulate size, density and moisture content will force changes to the operating control algorithms and possibly some hardware changes.

We have made six runs with the MMBH unit during the month of January. The first couple of runs had problems with the engine surging during the startup mode while running on propane. The surging condition made it difficult for the Trace inverter to synchronize the frequency and add load to the generator. We found that dropping the running frequency a couple of HZ (61 to 59 HZ unloaded) helped the Trace inverter to add load. We also connected the integral alternator of the engine to the starting battery. The added load of the alternator helped stabilize the engine and the last several starts were free from the surging condition. The Trace inverter was then able to add load immediately. The other problem we had encountered was during the transition stage. When the gasifier is first ignited, the gasifier consumes oxygen and produces inflammable gas mixtures. The engine is consuming this inflammable gas volume and responds by opening the throttle to compensate. The engine throttle was going to the full-open position and still dropped the frequency below the minimum allowed by the Trace (55 HZ). There was enough pressure drop through the combustion air valve that too much inflammable gas was being pulled through the engine, even though the combustion air valve was wide open. A larger combustion air valve could not be used, since the valve operates in the 10% to 20% open range while the system is running on producer gas. The valve is uncontrollable below 10%. The solution was to add a small, 3/8" solenoid valve into the producer gas stream piping. This solenoid valve is temperature-activated to open while the gasifier is producing inflammable gases and shut when the gasses become more flammable (CO_2- CO conversion). The last two runs with this valve installed allowed for successful transitions.

SMB Field Test Sites

Walden Site

The Walden site has been operating regularly and has not had any significant problems since the heat exchanger was replaced last month due to heat induced mechanical stresses and weld separations.

The single mechanical failure was a cal rod, which was replaced. The failed cal-rod has been returned to CPC for a failure analysis. Preliminary inspection shows that there was molten metal deposited on the outside of the cal-rod, which suggests that it had shorted out. An alternate failure mode is if the controller program is re-started and the char bed hot, the cal-rod could be re-energized and overheated. A conditional statement has been added to the new code to shut off power to the cal-rod, if the grate temperature is over 700°C.

The SMB at Walden has accumulated 152 hours of run time to date. Recently when the gasifier output pipes were opened to address a leak at the clamp between the gasifier and the char pot. When the clamp was removed the operator found nails, nuts, bolts, and even a small saw blade stuck down at the bottom of pipe. The objects found there were not related to the air leak, but indicate the significant amount of tramp material that is being introduced into the gasifier with the feedstock and passing through the grate.

Ruidoso Site

The BioMax 15 has been run approximately 105 hours since operation began at SBS shavings in early October. It was operated on January 5th and 7th this month.

The operator at the Ruidoso site quit his position in January, leaving the system unattended. Even thought the principals at the site (Glenn and Sherry Barrow) have been trained in the running the system, they have elected not to run it, probably due to manpower limitations in running the main business. We had a trip scheduled to both New Mexico sites in mid January to perform code upgrades but at the request of SBS Shavings, we cancelled the visit to Ruidoso pending the hiring of a new operator. Additional training can be conducted as part of a follow up visit, but it is clear that the commercial pressures on the business at SBS Wood Shavings and the shortage of manpower impose significant limits on the ability to support the system at that site.

Zuni Site

CPC's field engineer traveled to Zuni the week of January 19th and successfully installed and debugged the new software. Some hardware incompatibilities were resolved and some minor maintenance was performed prior to discovering an air leak that was causing the engine to perform poorly. Although a full set of maintenance equipment was conveyed with the system during its original deployment CPC had to air ship some pressure testing hardware to complete the pressure tests. Testing revealed a leak at the gasifier gasket; this was fixed and the unit was returned to normal operation on January 26th.

A summary of the engine emissions testing, performed at CPC by NREL in June with the Ruidoso unit, has been forwarded to ZFE. These data suggest that the emissions with a catalytic muffler are sufficiently low to meet the requirements of California for distributed combined-heat-and-power systems. It is hoped that this will satisfy the local EPA requirements at Zuni without performing extensive field emission tests.

Activities for the Next Reporting Period

All three sites will continue to be monitored on a daily basis until operations are routine and relatively stable. We will continue to be ready to provide any assistance that may be required to support the sites.

Ongoing R&D will continue in the area of engine controls. As improvements are achieved and confirmed in testing we will upgrade each site as quickly as possible. The restructured software code and gasifier control algorithm upgrades will be implemented at all of the sites in the next reporting period.

Problems That Need Resolution

CPC's experience over the past six months with the BioMax system at SBS Wood Shavings (Ruidoso) shows that SBS Wood Shavings has been unable to meet the stated requirements in the formal cooperation agreement with CPC to provide two, part-time, operators for the BioMax system. This is understandable given the extreme pressures SBS is facing in the startup phase of business operations. Glen and Sherry have frequently mentioned to CPC that they are stretched to the limit and simply can not afford the extra time it takes to operate the BioMax system. Since installation, two SBS employees assigned to operate the BioMax have quit within a few months after on-site training by CPC field engineers. The budget for support of the BioMax systems is not adequate to continue to provide on-site training for replacement operators at Ruidoso.

COC recommends that NREL and FPL give serious consideration to removing the BioMax system at Ruidoso. Relocating the system to a new site and training of operators will require additional funds.

CPC looks forward to working with NREL and FPL to resolve this situation to everyone's satisfaction.

Attachment B: Subcontract Financial Status

Project: Community Power Corporation - Small Modular Biopower			**Date:** 01/31/04
General Information: In Phase 2b CPC will continue to develop their SMB system. Highlights of the effort include incorporating SMB improvements into new units, providing five SMB units for the USFS/DOE initiative for utilization of forest residues, obtaining independent confirmation of SMB system performance and emissions, and continuing development efforts, e.g., the Philippines and Iowa.			
Project Participants			
Contact Name	**Telephone Number**	**FAX Number**	**E-mail**
Robb Walt	303-933-3135x222	303-933-1497	rwalt@gocpc.com
Period of Performance: 9/23/99-9/30/05		**Contract Amount:** $6,222,993	
Legislative			
Senior Senator: Ben Nighthorse Campbell	Committees: Appropriations; Energy and Natural Resources; Helsinki Commission; Indian Affairs; Veterans Affairs; Security & Cooperation in Europe		
Junior Senator: Wayne Allard	Committees: Budget; Armed Services; Banking, Housing, and Urban Affairs; Select Committee on Intelligence; Environment & Public Works		
Congressperson: Thomas G. Tancredo (6th CO)	Committees: Budget; International Relations; Resources		
Contracting Office: NREL	**Contract Manager -** Randy Combs **Phone/FAX/E-mail**:303-275-4442 303-275-2943 (F) randy_combs@nrel.gov		
Technical Support Team			
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Project Schedule - Phase 2b, FY02			
Project Milestones	**Schedules**	**Status**	
Establish baseline emission profile	June 2003	Completed	
Implement hardware & software upgrades to field units	August 2003	Completed	
Deploy 3 units to field	October 2003	Completed	
Develop commercial structure	January 2004	In Process	
Final Report	September 2005		
Funding Summary		**Invoiced to Date**	
Phase 2a	Funding - $1,279,215 Cost Share - $1,279,213	$1,279,215	
Phase 2b Funding - FY01-03 FY04	$1,995,232 350,000		
Current Cost Share Amount	$1,562,698		
TOTAL	$3,624,447		
Total Federal Contract Value	$ 3,624,447	$3,367,332	
Total Cost Share	$ 2,598,546	$2,605,298	
TOTAL	$ 6,222,993	$5,972,630	