MILESTONE REPORT

Executive Summary: During this milestone period, the Energy & Environmental Research Center (EERC) completed Milestone 8; commencement of system construction. During this reporting period, the EERC completed the installation of the new auger for the gasifier. Additional testing on wood chips and coal chunks ¼”-1” produced consistent combustible gas with no clinker problems. An additional cyclone was added to the system to reduce fines, and the feed system and gasifier system re-plumbed for connection to the microturbine. Work is ongoing on Milestones 9-12. Project funding was provided by customers of Xcel Energy through a grant from the Renewable Development Fund.

Technical Progress:
In the prior quarter, the gasifier successfully gasified coal char, wood char, coal, pine wood, oak pellets, and wood bark. Cold syngas composition was similar for all feed stocks and characterized by high CO content (~15-23%), medium hydrogen content (~6-12%), and low oxygen and methane content (~2-4%). Carbon dioxide was approximately 10% ± 2%. Gasification of coal char and coal produced substantial clinkers that adhered to the refractory, just above the air inlet nozzles. Clinker formation advanced radially inward with continued operation of the gasifier on coal and coal char until both the air nozzles and feed were choked. The vertical auger was extended above the air nozzles to break up clinker formation and the material for the auger was changed to stainless steel 310 to allow operation of the auger in the hot zone of the gasifier.

Testing recommenced on wood chips, coal composed primarily of fines, and coal sieved to chunks sized ¼” – 1”. Testing of the coal composed primarily of fines produced excessive entrainment of fines in the syngas. After sieving the coal to ¼” – 1” chunks, the gasifier operated reliably through extended runs with a thermal profile indicative of a slurry gasifier with a constant temperature from the air nozzles to the char extraction auger of 550 – 600 ºC. Operation on wood chips produced a thermal profile indicative of a co-current fixed bed gasifier. Inspection of the inside of the gasifier and vertical auger after testing showed no signs of clinker formation.

A second cyclone was added to the system to further reduce fines entrainment and the system re-plumbed to make ready for connection to the microturbine. Figure 1 is a simplified schematic of
the completed power system. The portions enclosed within the dashed lines denote the portion of
the power system tested and ready for connection to the microturbine. Figure 2 is an image of the
feed system and gasification system re-plumbed for connection to the microturbine.

In addition to the work performed on the gasification system, testing and optimization of the
microturbine continued in parallel work. We were able to overcome start-up faults and operate
the microturbine at low speed (~30,000 rpm). At higher speeds (~60,000 rpm) the air flow into
the combustor increases dilution air and reduced the fuel-air mixture below the flammability
limit of methane. This will be addressed by adding combustion nozzles with a pre-mixed fuel-air
mixture for start-up. In addition, initial observation of the airflow patterns in the microturbine
allows the addition of fins to the heat exchanger. Since both the heat exchanger and combustor
are integrated into a single unit, breakdown of the microturbine to add combustion nozzles
provides an opportunity to add additional fins to the heat exchanger, increasing heat transfer
from the combustor to the high pressure air.

In the upcoming quarters, additional modifications to the combustor and heat exchanger will be
made to optimize heat transfer from the combustor to the high pressure air. Combustion nozzles
will be added to the combustor to control the fuel-air ratio, providing better flame control from
start-up to ramp-up of airflow through the turbine. The surface area of the heat exchanger will be
increased to provide better heat transfer from the combustor to the high pressure air. Testing of
the microturbine will continue on natural gas after the microturbine modifications are made. The
input to the microturbine combustor will then be tied to natural gas for start-up, and the gasifier
output for steady state operation. Both short term and long term testing is planned.

Figure 1 Simplified schematic of biomass power system.
Additional Milestones: Work has commenced on Milestone 9 – 12 (power system construction and testing).

Project Status: With the completion of Milestone 8 the project is on schedule. Completion of the microturbine testing and subsequent connection to the rest of the system will complete
Milestone 9, complete power system construction. This is expected to occur within the next or subsequent quarter.

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