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Biomass Gasification: A Comprehensive Demonstration of a Community-Scale Biomass Energy System

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Section II: Biomass Toolbox

Author

Michael Reese
University of Minnesota, WCROC

SUMMARY – BIOMASS TOOLBOX

Biomass Gasification: A Comprehensive Demonstration of a Community-Scale Biomass Energy System

Overview

Biomass provides opportunities for rural economic development, diminishes the impact of greenhouse gases on the environment andprovides a viable alternative to natural gas and other fossil fuels, while decreasing the need for foreign sources of energy. Despite these facts, technology deployment at the beginning of this project in March 2005 was sparse across the United States. Without deployment, there were limited capabilities to develop information for sustainable management of biomass resources. With the support of, and partial funding from, the State of Minnesota, the University of Minnesota, Morris (UMM) took a bold step forward by investing $6 million to add a biomass gasifier to its current district heating and cooling system. Funding from other sources including the USDA / DOE Biomass Research and Development Initiative added $3 million to enhance the research and demonstration capabilities. In addition to being an operating system, the facility acts as a University research platform for the development of community-scale biomass energy systems. The UMM system provides a combined heat, cooling, and power production model that can be duplicated across a wide range of facilities including rural hospitals, schools, courthouses, production and manufacturing facilities, apartment complexes, and residential housing served by municipalities. The gasification system also provides research opportunities in developing bioproducts from the synthesis gas stream.

This project allowed us to develop a Biomass Toolbox to be used for continued deployment of biomass gasification systems across the United States. The described here (Section II) includes:

1. Standard Operating Procedures (SOPs) for biomass gasification systems
2. Best Management Practices (BMPs) for biomass cropping systems
3. Templates for market contracts and pricing structures based on biomass feedstocks.
4. Financial and cconomic impacts
5. State and federal environmental permitting procedures for biomass gasification systems
6. Guidelines for developming a sustainable biomass supply chain
7. Outreach information and web portals
8. A case study in biomass preprocessing

Volatile natural gas and fuel oil costs experienced in recent years have been devastating to rural businesses, local governments, and schools. For most communities, a viable solution exists in crops grown in nearby farm fields. However, there have been obstacles in utilizing this resource. The Biomass Tool Box developed by the project team provides critical information for the advancement and development of biomass gasification systems in rural communities.

The project team identified several bottlenecks that restrict deployment of this technology. Most of these challenges are universal and face any community investing in a biomass gasification system. USDA/DOE funding allowed us to address these obstacles and to develop tools enabling further deployment of biomass gasification systems. Guidelines were created to promote parallel development of sustainable biomass cropping systems. Six different streams of biomass feedstocks were demonstrated: corn stover, corn cobs, wheat straw, soybean residue, native grasses, and wood. Information obtained from the test burns was used to develop the Biomass Toolbox. Capstone classes and web portals along with several other outreach activities were used to disseminate results.

The diverse project team included personnel from the University of Minnesota, USDA-ARS North Central Soil Conservation Research Laboratory (NCSCRL), Chippewa Valley Ethanol Company, and HGA Architects and Engineers. Several other stakeholders were involved in developing the biomass gasification system and in completion of the deliverables.

Development and operation of the UMM Biomass Gasification System proved to be a significant challenge for the project team. Despite and perhaps because of these challenges, the project team believes the results from this project can be invaluable to those considering a biomass gasification system. Due to the uniqueness of the community-scale biomass gasification system, there have been several barriers to successful operation - some known and some unknown prior to the beginning of the project.

History and Key Milestones

Initial discussions on developing a biomass energy system began in year 2000, primarily due to volatile natural gas prices and supply to the rural University of Minnesota, Morris campus. The adjacent University of Minnesota West Central Research and Outreach Center began researching biomass energy options. In late 2001, discussions were held with the University of North Dakota Energy and Environmental Research Center (EERC) about the appropriate steps for beginning a project. All agreed the first step was a Biomass Resource Assessment which would determine how much biomass feedstock was available in a radius around the UMM campus. Researchers at the EERC focused on non-agricultural biomass and found that 677,000 tons of biomass feedstocks were available within a 100 mile radius of the campus. The campus was projected to use 7,000 to 9,000 tons per year. With the available biomass resource information in hand, the project team launched into an effort to fund, design, permit, procure, construct, and operate a biomass gasification system with the goal of providing 80 percent of the UMM campus' heating and cooling needs. Following several delays, construction began on the biomass gasification system in July of 2007. Major completion of the facility was completed in Fall 2008.

Key Findings

Since the ceremonial commissioning in Fall 2008, there have been several significant challenges the project team continues to address in system operation. As part of the deliverables, critical information has been developed and included in this report in response to many of the challenges. Detailed accounts of the challenges and findings are located within this report. As an upper level view of the key findings, the primary challenges experienced include:

- Small number of available suppliers for the appropriate size of gasification system
- Minimal experience of engineers and suppliers with agricultural residues
- Lack of efficient and cost effective biomass handling and processing systems
- Cost overruns due to added design and facility requirements
- No experience of the permitting agencies with agriculture residues in biomass energy systems
- Design issues with both the facility and the equipment
- Hesitation of facilities planning and administration due to the disruptive nature of the technology
- Limited knowledge of appropriate operation parameters to achieve gasification for diverse feedstocks
- Feedstock storage, handling, processing, and densification issues
- Control limitations on the gasification equipment
- Limited understanding of staffing requirements for both gasifier operation and supply of biomass
- Difficulty in balancing multiple goals of research, demonstration, and commercial operation
- Diverse feed stocks characteristics including moisture and density

Proper density of the feedstock required for gasification within the UMM system remains an ongoing challenge. Even though loose corn stover was specified as the primary feedstock to the gasifier supplier, after several test burns and consultations with experts in the field, the project team found the biomass gasification system required denser biomass feedstock. As a result, the project team launched into an effort to find appropriate and cost effective feedstock densification systems. Several densification systems were tested with corn stover and other biomass materials. The resulting densified materials were tested in the gasifier with varied success. Wood and corn cobs appear to work the best within this type of gasifier while small grain straw burns too hot and therefore does not achieve gasification.

Discussion of Deliverables and Implications

The Biomass Toolbox deliverables are intended to be used as templates for entities wishing to pursue and develop community-scale biomass gasification systems. The templates are meant to be used as a development guide and not as a location and site specific manual for individual projects. Depending on the technology utilized, location, feedstock, and several other factors, actual operating conditions can vary widely. Individuals must carefully conduct their own due diligence and consider operating practices prior to installation of a biomass gasification system.

The Standard Operating Procedures (SOPs) developed within this report are primarily for an inclined grate, above and below air-fed gasification system utilizing wood and agricultural residues. Many of the same principles apply across different gasification systems but SOPs should be carefully considered for each individual case and circumstance. Prior to operation, care must be taken to match the gasifier type and handling system design with the expected biomass feedstock. Key operating information to consider includes:

- Biomass availability and cost
- Delivery to storage site, testing, and acceptance of loads
- Proper storage including fire lanes, protection from the elements, and maintenance (dust, rodents, mud, etc)
- Processing and densification
- Efficient delivery and feeding of the gasifier
- Biomass available for extended run time and consideration of scheduling staff shifts for biomass delivery
- Cleanliness, moisture, density, and chemical characteristics of feedstocks
- System startup and shutdown procedures
- Proper feeding rate of the biomass material into the gasification system
- Control of air entering the gasifier
- Control of temperature within the gasifier and combustion chambers
- Removal of ash and fly ash from the gasifier and emissions stream
- Mitigation of emissions such as balancing pH and removing particulates
- Control of pressure and temperature within the boiler system
- Monitoring of thermal energy production and energy balance
- Sampling and testing of emissions and ash streams
- Removal and proper disposal or preferably field application of ash
- Appropriate staffing levels to meet regulatory compliance as well as operational requirements
- Reporting to appropriate agencies and departments
- Scheduled and unscheduled maintenance and repairs

Best Management Practices (BMPs) for biomass cropping systems are meant to ensure farmers (as biomass producers) are able to sustain biomass production and soil health. For example, the over harvesting of biomass will result in a decrease in soil organic matter which will contribute to poor soil health and ultimately low yields. BMPs were compiled and a decision matrix tool was included for farmers to gauge the proper levels of biomass harvest from their individual farms and soil types. Nutrient management considerations also play an important role in decisions by farmers to harvest biomass. The removal of biomass residue results in the removal of nutrients. Therefore, farmers need to evaluate the replacement levels and costs when determining whether to harvest biomass.

A template was developed for market contracts and pricing structure of biomass feedstocks. The template was primarily developed as a result of the need for UMM to purchase and secure feedstock for the gasification system. Several key considerations when considering contracting and price of biomass include:

- All contracts need to be tailored for individual circumstances
- Utilize a local representative to be part of the contracting team in order to address location specific issues
- Consider a goal of developing long term business alliances with the local biomass producers
- Flexibility in the contract terms can be important for both the purchaser and seller
- Precise delivery dates are not always achievable by small operations that may serve a typical community-scale biomass energy system
- Purchasing agents need to balance the enforcement of contract provisions with the possibility of alienating all local suppliers of biomass
- There may be increased competition for biomass as more systems come on line in a region
- Education is important in describing the expectations and terms of the biomass suppliers
- Purchasing price for feedstocks is usually established on a bone-dry basis which may be unfamiliar to suppliers
- Clearly define acceptable levels of quality including moisture, spoilage, shape, packaging and wrap, and non-organic material (dirt, cans, etc) – Use caution in procuring ditch hay
- Clearly define expectations in pricing (eg . fuel surcharges), weighing (eg. Within 10 mile radius of storage site), and delivery (eg. Only between 8 am and 5 pm)
- Have precise standards for dockage, non-acceptance, and defined transfer of ownership (eg . upon delivery and acceptance)
- Expect to have staff responsible for on-site inspection, testing, and acceptance of delivered biomass material
- Consider the seasonality of supply and delivery (eg. Farmers may not wish to deliver during harvest as they are too busy or they may wish to deliver all biomass within a very short window)
- Maintain communication between the supplier and purchaser of the feedstock

The project team learned that biomass gasification systems can have financial and economic impacts for the owner, community, region, and state in which they are located. The University of Minnesota, Morris biomass gasification system ended up being more capital intensive than originally anticipated. However, during the same time frame the alternative, fossil fuels such as natural gas and fuel oil, also spiked in price and remained extremely volatile. Capital costs were also higher due to the multiple goals of the system including research, demonstration, and commercial operation (supplying heat and cooling to a 2,000 student campus). The University is also unique compared to a private entity as there are generally more demanding code compliance requirements and higher construction standards due in part to bond financing. Operation costs were slightly higher than anticipated due to added staffing requirements, increasing feedstock prices, and processing and densification requirements. Planners should account for added labor in biomass handling and logistics operations as well as typical losses of biomass from handling and spoilage. Even though there was a requirement specified to the gasifier supplier for the system to operate with undensified corn stover, the system ultimately required significant processing and densification. Unanticipated operational expenses were incurred as a result. Planners should insist on testing and verifying operation of a gasifier with the specified biomass material prior to purchase and installation. From an owner standpoint, biomass can be cost effective under the correct circumstances. The economic analysis indicated a benefit to the community and region including adding jobs and maintaining local dollars in the economy. As a small pilot plant, there was a net benefit to the state but the increase was also small. Obviously more deployment of community-scale systems would have a much larger impact across the state and nation. The primary economic benefit resulted from keeping approximately $500,000 of energy dollars within the region through the purchase of local biomass.

The report includes general and site specific state and federal environmental permitting procedures for biomass gasification systems. The gasification of agricultural feedstocks can result in unique challenges with respect to emissions. For example, the project team found during initial emissions testing prior to construction that corn stover gasification resulted in emissions with a low pH level. The caustic emission stream would potentially be harmful to the equipment, pose a potential environmental hazard, and in addition create ash with a high, that is, basic pH. Therefore, a mitigation system utilizing sodium hydroxide sprayed into the emission stream was designed for the UMM gasification system. The project team also found the permitting agencies lacked the necessary data and experience to simply issue a permit. Test burns utilizing established gasification systems were required along with independent verification of emissions data. Permitting agencies do now have more experience in permitting biomass energy systems but the more unique the feedstock the more time and due diligence is required.

The chapter “Guidelines for a Sustainable Biomass Supply Chain” referencesthe long term procurement and utilization of biomass feedstocks. Energy systems are usually designed for 20 or more years of service witha system that designed specifically for one feedstock. There can be several scenarios in which one or more of the operating years, a singular feedstock may not be available. The scenarios include crop failure, market and government farm program changes, loss of processing facilities, or simply agriculture producers who cannot afford the time and expense of providing biomass feedstocks. Ideally, the planning process and system design will account for the utilization of multiple feedstocks. One of the first steps in the planning process is to identify sources for biomass feedstock. The sources can be broadly broken into agricultural, forestry, and industrial by-products. Once the sources in each of these broad categories and willing sellers have been identified, the planners should evaluate the life cycle environmental impact of each feedstock to ensure long term sustainability including but not limited to the impact of removal, ash, and emissions. A financial feasibility analysis must be made. There are other considerations within a supply chain including availability of efficient delivery, storage area and facilities, processing equipment and methods, and additional labor and training requirements. Logistics are key in a sustainable supply chain. The project team recommends careful evaluation and study of the various roles and responsibilities within a supply chain. It is easy to underestimate the amount of labor and equipment required within each of these roles - especially the amount of time and oversight required to receive biomass at the storage site and then deliver the material to the gasification system.

The project team developed considerable experience and outreach materials during this project. The lessons learned, supporting documentation, and outreach materials are available via our website at http://renewables.morris.umn.edu/biomass. A web portal is available at the same web link in which real time video, infra-red video, and data from the UMM biomass gasification system can be observed during gasifier operation. Finally, the project team hosts visitors from around the world. Anyone interested in visiting the UMM Biomass Gasification System and project team members can request a tour on the web link or call the University of Minnesota, Morris at (320) 589-6407 or the West Central Research and Outreach Center at (320) 589-1711.