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

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Chapter 4: Financial and Economic Analysis

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Preface: Project Economics

One of the motivating factors in conceiving, designing, and building a biomass gasfication system was the potential to bring economic development and/or energy cost savings to the community. Therefore, various economic factors have been monitored during facility construction and the startup process. To evaluate the project economics at different levels, two analyses were done using different types of economic data and estimated expenses of feedstock procurement and facility operation. The first study looks specifically at operations of the biomass plant and the differences between dollars spent on natural gas at the pre-existing plant and the cost of operating the new biomass gasification facility. These data are best used for investors and others looking at profitable operation of a facility that they may be considering. The calculations, data, and spreadsheets can serve as a template for others to assess how a planned facility might function financially. These templates are available from the project team upon request and are included on a CD with official copies of the document.

The second analysis is a higher level analysis of how a biomass facility might impact community economic development. Developed with an industry standard economics model (IMPLAN) that uses community data from counties in the region, the analysis assesses the potential for income and job development in the community. Meant to guide professional economic planners, the data provide an overview of how resources flow through the community based on the addition of a biomass facility. As a detailed technical analysis, it lays the groundwork for community response to the various resource inputs and outputs. While there are some general conclusions that can be taken directly from the report, it is designed as a tool to demonstrate community economic benefits and is for use by economics professionals.

Study 1: The Morris Gasification Plant Economics

I. Introduction

This section describes the basic financial considerations of the Morris Gasification Facility. While it provides a valuable set of financial numbers for those interested in biomass energy, these numbers are preliminary and derived from limited operations during plant startup. They are more refined than early predictions (HGA 2003, Brun 2007, Toso 2008) because staff have more experience working with biomass and know more about the processing steps that will be needed for future operations. In addition, labor and maintenance costs can be predicted more reliably. However, these data are still from a very transitional period at the start of facilities operation. This analysis is not meant to be a full economic analysis, but a basic description of construction and operational expenses.

In order to more fully understand the plant economics at this facility, it is first important to recognize the reasons the University of Minnesota elected to go forward with developing a biomass powered heating plant and how a university project might differ somewhat from a private venture. By the 2000-2001 school year, several factors forced the University of Minnesota, Morris campus facilities staff to begin discussing the existing natural gas and fuel oil district heating and cooling system and future strategies for campus heating and hot water needs. A significant concern was the rapidly fluctuating costs of natural gas (NG) that fired the campus' steam boilers. Volatile natural gas prices had increased two fold in a three year period between 2002 and 2005 (Figure 1). In addition, for several days each year NG supplies to the Morris campus were curtailed by the regional supplier because of high demand. The curtailment necessitated the use of fuel oil to heat the campus. Switching the dual fuel boilers to fuel oil is more expensive and produces more pollution than NG use. Another concern was the age of the plant's original boilers, which were installed when the plant was built in 1971. Though a new boiler had been installed in the mid-90s, the original boilers were near the end of their useful lifespan. A new boiler system was needed to maintain the redundancy required for heating a residential campus in a northern climate. Another aim of the project was to explore alternative community based energy sources. The University has a role in fostering innovation and demonstrating new technologies that can enhance Minnesota communities. Over $800,000 dollars per year in natural gas payments were being sent to other parts of the country or the world to supply heat energy for the Morris campus. Based on their situation, the Morris campus began working on the feasibility of a biomass fired boiler system.

As a University endeavor, the Morris Biomass Project is not directly comparable to a private venture. One obvious difference is the fact that a private venture would likely require a significant rate of return on top of any energy or cost savings. Other economic differences include the lower public bonding costs for a public project versus the cost of investment capital needed on a private project. University of Minnesota projects also tend to be built using more stringent building codes and standards than a private facility, due to safety and longevity issues for the 150 year old state institution. University costs are also greater than would be expected in general for rural Minnesota, due in part to University prevailing wage rules based on Minneapolis-St. Paul area salaries. Another factor making comparisons difficult to quantify economically is the value of the facility as a research and demonstration component of the Universities' renewable energy education and research efforts.

An initial feasibility study in 2004 provided the first look at tentative feedstocks, equipment and costs for a campus biomass powered heating plant (HGA 2004). Early plans were for combusting biomass in a standard combustion system which, combined with a new steam driven absorption chiller for cooling, would cost around $5.1 million to construct. However, the availability of clean burning wood biomass in West Central Minnesota is somewhat unreliable. Agricultural residues are a better regional biomass resource because of their much wider availability. Plans were changed to use a biomass gasification system rather than a combustion system. Gasification can be used to produce heat energy from agricultural residues such as corn stover and wheat straw, which are difficult to directly combust due to several factors (see Section II, Chapter 8). Being in the Corn Belt, the 10,000 tons of biomass needed annually to fuel the facility could quite easily be supplied in the immediate Morris vicinity. Plans for the project went forward with construction of the facility beginning in summer 2007.

The expected final completion date for the construction was anticipated to be spring of 2008, with commissioning and final acceptance of the plant in April of 2008. However, project construction activities and equipment tests did not go as planned. The construction and operations difficulties have also very significantly altered the long term ability to use some biomass fuels and the forms of those fuels that can be used. Biomass feedstocks were initially planned to be very minimally processed with little equipment needed to process material. It was planned that a simple 'shredder' would be used to break bales open and feed the system. Plant construction is essentially complete and, although the equipment is still very much in a testing phase, our early work reveals that some fuels may need to be more finely ground, densified, or dried prior to use. Changing the form of the biomass has several cost implications as does selecting specific feedstocks. These changes have a very significant impact on the fuel costs and subsequently the costs of operating the facility.

II. Economic Analysis

This economic analysis is an effort to review the current economic predictions for the biomass gasification facility. It is important to stress that the numbers are not known costs of a fully operational plant, but predictions based on recent biomass fuel costs and estimates of plant expenses during our initial testing phase. To better analyze plant operation expenses, costs were divided into three categories: labor, fuel and maintenance. Both because of the background of the authors of this analysis and the desire to keep the content more useable by a wider audience, the document does not include time value of money calculations. Similarly, simplified yearly costs for equipment are used for auxiliary equipment. As a public institution, depreciation and other tax implications were not included in the analysis but may have a significant impact for private entities. Templates for the analysis are available from the authors upon request and can be used to model different fuel, labor and other costs.

Capital Costs

In 2003, a wood fired steam production facility with a combustion system, boiler, and steam driven absorption chiller was predicted to cost roughly $5.1 million dollars. Options that might have been added to that facility included generating additional electricity with a steam driven turbine generator and linking up with other community facilities that share energy production infrastructure. Final approval for construction of a gasification facility was granted by the Regents of the University of Minnesota in 2007 and was set for $8.9 million in construction costs. The funded facility included the building, biomass gasification equipment, boiler, emissions scrubbing system and research equipment. By the end of 2008, major construction had been completed on all systems. The initial construction was close to the budgeted $8.9 million. However, equipment was not functioning as planned and needed some alterations. While contractors for the equipment that did not operate as anticipated have stepped up to work with the University to get their equipment fully operational, the University has expended additional funds to overcome design constraints with the system. With some consultants continuing to assist with system optimization, definitive final costs are not available at this time (Table I).

Labor

In estimating labor costs for the biomass gasification plant (Table II), the assumption was that UMM staff would supply all labor for gasifier operations for the near term. The long term goal is to have a contracted aggregator who supplies much of the labor associated with biomass handling and storage operations. An outside aggregator would likely be less costly to the University due to lower labor and overhead rates. Additionally, the labor costs are based on current research and startup operations. Labor costs will likely be reduced with more operator experience and better understanding of the specialized needs during research studies. An important item to note in the labor costs is that the gasification labor costs documented here are above current costs for the existing plant. One certified boiler operator has always been required on-site at all times for operation of any pressurized boiler. That operator will be in charge of operations of the gasification system.

The largest additional labor cost for the facility is for biomass handling and logistics. Stocking fuel in the in feed system will require a full time employee. In addition to the moving fuel, the employee needs to maintain the cleanliness of all storage sites and equipment. The time estimate for this is approximately 50 hrs a week, with five 8-hour shifts during weekdays and two 5-hour shifts on the weekends. Managing the biomass gasification facility will also take additional labor for activities such as tracking biomass purchases and shipping, quality control, and emissions documentation. Estimates for this are that a little less than a half time position (15 hours per week) would be needed to coordinate activities associated with biomass plant operations. The final area where additional labor is needed is in maintenance, with an estimated average of 20 hours per week needed. This average figures in scheduled yearly down-time work, regular cleaning of components, and unscheduled repair of components. At a rough University rate of $30 per hour (salary and benefits), the total weekly and yearly costs are approximately $2,550 and $132,600 respectively.

Early efforts to guide the gasification system through startup and determine operating parameters required much more labor than had been estimated at the beginning of the project. The estimated operational labor presented in table II is based on the current knowledge of facility operation, use of a wide variety of feedstocks, handling of biomass with less than ideal equipment and some inflexibility in staffing. There are several areas where labor costs could be reduced over the long term, many of which are easily done at a non-research facility. The chief labor concern for most biomass projects is the biomass receiving and handling operations. Biomass handling efforts can be lowered by reducing the number of feedstocks, purchasing or designing specialized handling equipment for those feedstocks, and using well designed quality control/quality assurance procedures to maintain uniform feedstocks that can be fed consistently through feedstock handling equipment. Private facilities also have more options for negotiating with staff to optimize work schedules and salaries.

An aggregator may also be an effective way to mitigate the costs of labor expenses for biomass logistics. The aggregator is an outside party with expertise in biomass logistics who is contracted to work with biomass. The specific duties of the aggregator vary considerably (see Section II Chapter 5) but typically include supplying the labor, equipment, and management for the feedstock supply chain. With a narrow focus of work and more expertise in the logistics process, a biomass aggregator has the potential to optimize labor and reduce costs. The long term view by many in the industry is that most business models will use some sort of aggregator, however the extent of cost savings by using a third party cannot be determined with the limited data at this time.

Operations and Maintenance

With a first-of-its-kind facility, operations and maintenance (OM) costs are difficult to estimate accurately bases only on start up activities. The estimated OM costs are presented in Table III. The costs were developed in consultation with operations staff at the Biomass Gasification Facility and from estimates provided by project architects and engineers. Costs were divided into three categories: auxiliary equipment, maintenance, and supplies. In-house labor costs for maintenance were not included under OM expenses, but were placed directly in the labor expense category (Table II).

Several pieces of auxiliary equipment are needed by the facility to handle biomass logistics. Although the University has been sharing existing equipment from other operations to start up facility operations, it is anticipated that the facility will need its own equipment for full time operations. The equipment specified in Table III is fairly standard equipment for facilities working with biomass. Prices for the equipment were based on a random selection of used equipment found online in conjunction with input from University staff having some experience in the used equipment market. A simple calculation of annual costs was made by adding up the total cost of the equipment and dividing it by the estimated lifespan of 10 years. In addition, an annual cost of equipment operation was estimate to be around $13,000 per year based on fairly light use and factoring in-house maintenance with labor included as part of facility labor (Univ. of Wyoming).

Annual maintenance costs include parts and supplies needed to maintain the system and an annualized cost for refractory maintenance (HGA 2004). Periodically, the refractory lining of the gasifier will most likely need to be patched by an outside contractor. The average yearly cost of refractory work was estimated at $12,000 per year factored over the refractory's lifespan. Other more standard maintenance for a system with these components includes the supplies needed when changing filter media, replacing sensors, installing new drive belts, and other miscellaneous parts.

Operational expenses do not include costs for maintaining emissions monitoring equipment. The constant emissions monitoring (CEMS) unit used at the biomass facility is for research purposes and was not mandated by regulating agencies based on the size of the facility and factors related to the unique situation. Similarly, other supplies for research sampling of water, air, and ash streams were not included in OM costs.

Fuel Expenses

To provide a perspective on typical NG expenses, facilities data from 2006-2007 was examined for energy use (Brun 2006), cost per million British thermal units (MMBTU), and total costs. The data (Table IV) also include an estimated conversion efficiency to arrive at the net MMBTUs of heat produced for that year. The total expenditure for NG was $760,763 for 92,776 MMBTU. The calculations do not factor in a small amount of fuel oil that was used in January and February 2007.

Though total biomass fuel cost predictions were not included in the 2003 feasibility report (HGA 2003), it is important to look at predicted costs as they are one of the initial drivers for the project. Because wood was suggested as the fuel in that report, energy value and costs data from the report were used in conjunction with the fuel consumption data from table IV-section A to estimate the predicted fuel cost in table IV-section B. Therefore using the 2003 predictions with the 2006-7 consumption data, the fuel costs for wood ($312,539 delivered) would have been significantly lower than for NG ($764,692 delivered).

As mentioned above, the biomass facility design was altered to allow the use of agricultural residues. There are significant cost differences between the waste wood that was envisioned in the 2003 report and the agricultural biomass that the facility is hoping to use. To fully explore the potential costs of using agricultural biomass, estimates need to include more details about agricultural residue logistics, storage, and processing. Tables V thru VII present three different cost scenarios for agricultural products, with estimated annual costs of biomass facility operation presented in Table VIII. Three scenarios were developed to factor in a broader range of fuel pricing due to a number of considerations related to feedstock economics.

The first consideration for the total cost of biomass fuels is the purchase price of biomass. For the University's gasification project, all biomass prices are stated as delivered costs. Vendors cover their costs of shipping and figure that into the price they charge the University. Initial government predictions were that agricultural biomass would cost around $50 per ton or less for agricultural biomass. Our experience is that the $50 value is lower than many farmers are willing to sell their material for at the present time. It may be that as producers gain more experience and purchase specialty equipment that they could sell biomass at the $50 dollar mark. However, the $60 to $70 dollar range is a more accurate per ton cost for delivered biomass in West Central Minnesota when farm equipment, labor, and nutrient replacement is considered.

Processing of biomass is the next major consideration for biomass costs. The Morris gasification facility has had difficulty using unprocessed materials, so has therefore been testing blends of loosely ground biomass with pelleted material. Because of the research and exploratory nature of the University's feedstock preparation efforts to date, they cannot be used for long term operational estimates. A more realistic estimate of processing expense is between $5 and $80 per ton of material depending on the type and level of processing needed. These numbers are from conversations with industry professionals and equipment operators who have discussed options with project staff.

Another important factor is storage of biomass feedstocks. This is especially critical for heavily processed biomass which, if it gets wet, will rapidly decay and introduce potential health and safety issues. Therefore biomass must be stored in a dry location once ground or densified. While ground material may survive unprotected for a few weeks, densified materials (pellets or briquettes) can and most likely will be ruined by a single rainfall or extended exposure to high humidity. Therefore facilities using these materials should be prepared for enclosed storage in protected bunkers or warehouse type buildings.

A key strategy to reduce the amount of enclosed storage needed is to have only a portion of the feedstock processed at any given time. Typically, this might mean having a two week supply of material in protected storage. For the cost estimates in this analysis, the scenarios use different volumes of biomass in protected storage. For facility costs, a lease rate of $3.00 per square foot per year for indoor storage space is used. This corresponds closely with a local facility that the University rented to store feedstocks in during 2009 and 2010. Other factors that were needed to calculate the square footage of indoor storage space and resulting cost were the bulk density of the material (lbs per cu. ft.) and how high the material was piled in the storage facility. The total cost of indoor storage was divided by the anticipated amount (in tons) of biomass run through the facility during the year. The resulting value is the per ton indoor storage cost for biomass.

The large volume of biomass needed for a biomass energy facility often means the majority of material will be stored outdoors, sometimes covered by tarps and/or on a gravel or crushed stone base that drains water. These facilities also have some costs, both a cost of using the land and an indirect cost of losing biomass due to decay. The land cost is fairly easy to calculate based on the local land rental value. The unearned income from renting the land is divided by the number of tons stored on the land to get the cost per ton for outdoor storage. Based on measurements of biomass stored near the biomass facility and what was calculated as being needed using a just-in-time delivery/storage strategy, 10 acres of land will suffice for the project's outdoor storage needs. Though not applicable to this project, site improvement costs may also need to be factored into outdoor storage.

Storage loss expenses are more difficult to estimate. Biomass decay rates vary from location to location with different climates, biomass types, and storage methods. In this cost estimate, a storage loss rate of 1% per month is assumed for outdoor biomass. While it may be an over-simplification, four months was used as the average storage time for materials for West Central Minnesota. The peak demand for biomass will be in the first four months after harvest (November-February), then demand declines as the summer months begin. In all models, this will result in a loss of approximately 4% of biomass. The percentage loss can be used to calculate the financial cost per ton by using the original purchase price per ton.

One factor not figured into this feedstock economics model is moisture. Moisture can influence the gasification process (Section II Chapter 8) and material handling, and can be a factor in calculating payment. For simplicity's sake, biomass was assumed to be 12-15% moisture. However, moisture may be a factor in efficiency, drying, and storage costs in a more complex model.

Economic Modeling

Using these costs associated with biomass fuels, maintenance, and labor, three different scenarios were developed to examine potential biomass costs for operating the University of Minnesota, Morris Gasification Facility. The scenarios are based on high, medium and low costs of biomass purchase, processing, and storage. At the bottom of each scenario, the calculated cost per ton of biomass is used to estimate the total annual cost of biomass (without labor and O & M) using the 2006-2007 NG consumption data. The individual fuel scenarios (Table V-VII) are followed by a comparison of all scenarios with actual energy costs for 2006-2007 and with energy prices at historic and current levels (Table VIII).

The first scenario (Table V) is the low cost feedstock model. In this model, the feedstock is purchased for an average of $60 per ton. Minimal processing (light bale breaking) is performed for a cost of $5 per ton and material is used quickly, thus indoor storage is not required. Though this is an overly optimistic look at costs in general, use of government programs such as the Biomass Crop Assistance Program (BCAP) may help bring the per ton cost of biomass into this range. Factoring in these costs, the biomass at the gasifier has a cost of $69 per ton. The corresponding biomass fuel costs are approximately $523,000 per year. With anticipated labor and O & M costs, this brings the totally yearly cost to run the facility to $724,000.

The mid-range estimate of costs (Table VI) has biomass purchase costs averaging $65 per ton. The processing costs average $20 per ton. The $20 per ton processing allocation allows for various combinations of high and low cost material processing, such as using some high cost densified material blended with low cost lightly ground material. Since processed material use is assumed, indoor storage capacity was modeled at 200 tons. Biomass costs per ton were $90 at the gasifier, which totaled $680,000 in fuel costs per year. When factored in with other costs, this scenario resulted in a yearly cost to operate the facility of $881,580.

The high cost scenario (Table VII) has biomass purchased for $75 per ton. In this model, all biomass requires processing at $50 per ton. A larger indoor storage area, with capacity for 400 tons, is needed to protect the high value processed biomass. The per ton costs of biomass ends up being very high at $131 per ton, which totals $993,000 per year. Total costs of operating a facility under this scenario are $1,193,000 per year.

Comparing Biomass Costs to Natural Gas

In order to determine how the prices of biomass would compare with possible natural gas (NG) prices, three annual NG cost scenarios that match a wide range of observed prices were developed based on the heating data from the 2006-2007 season (Table VIII). Since the labor used in the biomass facility cost estimates was over and above that used for the NG plant, labor is not added to the NG models. Supplies for operation of the NG boilers are fairly minimal and are not included.

The low cost scenario uses the lowest annual averaged industrial NG price from the 2001-2010 DOE-EIA natural gas data set ($4.02 per MMBTU in 2002), plus a regional delivery cost ($0.465) estimated using the difference between the UMM 2006-2007 energy costs and nationwide industrial NG prices for that period. The total estimated cost per MMBTUs was $4.485. The corresponding estimated yearly cost for UMM's NG usage is $416,098. Next, using the average NG price for the 2001-2010 period, the delivered price is estimated to be around $7.08 per MMBTU. The resulting cost of operating the heating plant is $657,036 per year. The high estimate for NG prices is based on the 2008 price of $9.65, which is approximately $10.16 per MMBTU once delivery charges are included. At the high estimate of $10.16, the annual costs to operate the facility would be $938,424.

Using these initial estimates of facility operational costs, it would appear that biomass gasification can economically compete with the use of natural gas for steam heating needs when the price of natural gas is high. The idea for the facility was developed during a period where NG prices were unstable and increasing rapidly (2001-2006). In fact, the facility was designed and built during a period of relatively high NG prices (2007-2008). The global economic downturn beginning in 2008 caused industrial demand for NG to drop substantially and prices fell considerably. Between June of 2008 and September of 2009 NG prices dropped by almost 68% from a record peak of $12.11 per MMBTU to $3.88 (DOE-EAI). As of the writing of this document (spring 2011), the price of NG has risen back to roughly $5.56 per MMBTU (Feb. 2011).

One of the reasons that the biomass gasification facility was an attractive option for the Morris campus was the ability to use a variety of feedstocks with relatively stable costs. The rapid changes in NG pricing had meant that the campus was using huge amounts of its budget reserves for heating costs as prices increased. By using a variety of locally grown fuels, the campus hoped to be able to select available fuels that would allow it to stabilize its campus heating costs. Another concern was the limited NG supply in West Central Minnesota. Due to weather and other factors, NG demand peaks above the regional supply. During these periods, the Morris Campus heating facility would be asked by the NG supplier to use its backup fuel in the duel fueled boilers. The backup fuel was #6 fuel oil which is expensive and burns less cleanly than NG. While the NG supplier discounted the cost of NG for the campus because of the campuses willingness to switch when needed, the fact that the campus was impacted by supply shortages made them think about what other fuels might be available to them.

Another factor in pursuing alternative energy for heating campus was to promote local resources. During peak NG pricing in 2007-2008, the campus likely spent around $900,000 dollars on NG during the fiscal year. Except for a portion in pipeline and management costs, almost all of that leaves the state and goes to wherever the NG was produced. Using biomass promotes local sustainability and maintains jobs in the region.

One of the final things to consider when comparing the economics of the University of Minnesota Morris Gasification Facility with the existing NG facility is its value as a research platform. Unfortunately, it is difficult to put a financial value on the ability to examine new renewable energy technologies. However, there is distinct value in being able to conduct research on new technology. University staff have begun planning and implementing additional funded research projects that are already adding financial and equipment resources to the gasification research.

Optimizing the Biomass Gasification System and Logistics

An important thing to remember with the data reported here is that the UMM gasification facility is the first of its kind. There is likely to be a significant opportunity for biomass gasification to be more competitive with NG going forward. Because UMM has little ability to influence NG prices, this means they will need to optimize biomass energy output and handling costs to become more energy and cost effective. In addition, selective switching between the biomass gasifier and existing NG systems might be an effective way to optimize the use of fuel and labor.

The most effective areas to target in optimizing biomass gasification system economics are biomass processing and labor. Both of these relate to the efforts needed to get the biomass from the landscape to the biomass facility in a form that will successfully gasify. As can be seen in Table VII, material handling and processing can add more cost to the feedstock than the cost of the biomass itself. An important place to start is developing biomass gasification equipment that can use minimally processed biomass. Mechanical processing is probably the single largest expense for biomass fuels.

The logistics chain is probably the next most significant expense for biomass systems. It should be designed to significantly reduce the number and scope of biomass handling operations that are required. While harvest site to facility transportation is obviously an important consideration, off-site transportation is often already a somewhat optimized process. Future machinery developments may improve this process, but this equipment is often outside the biomass facility's scope of activities. On-site at the conversion facility, automation should be used to reduce the amount of labor required for biomass movement. This is one of the low hanging fruits in reducing costs associated with biomass.

Another opportunity that will be pursued is the potential sale of co-products, which may be able to add an income stream to the gasification facility. Depending on the conversion technique used to extract energy from biomass, the ash or char may have value for use as a soil amendment to alter pH, increase fertility, or enhance soil structure. Another biomass facility in the West Central Region of Minnesota has established a business relationship with a fertilizer company to sell a biomass combustion ash product. Staff at the Morris facility are actively looking at their ash product and its possible use as a soil amendment. When the ash material from the Morris gasification plant is approved for land application, the researchers intend to test its efficacy and value as a soil amendment.

Outside resources for carbon credits, environmental stewardship practices, and policies designed to assist startup facilities are another possible source of funding to help offset current biomass energy conversion facility costs. Though carbon credits are not likely to be implemented in the immediate future, it is possible that at some point they will be available for renewable biomass facilities. At present though, federal programs such as BCAP (biomass crop assistance program) are available for some projects to provide funds to offset biomass costs. Low interest loans and tax credits are also possible resources to improve the economics of start-up facilities. Many states have renewable energy mandates that promote renewable power production by incentivizing or mandating that utilities add renewable production to their portfolio. In Minnesota, this has meant that the largest providers will pay a premium for electricity generated by wind, solar and biomass.

Innovations and creative solutions of all sorts will likely be the drivers that make biomass energy consistently competitive with low cost natural gas. The likely solutions will integrate new conversion technologies, enhanced logistics, better management, and creative financial models. The Morris Biomass Gasification Facility was designed to begin the process of developing these innovations, but also to establish the starting point for using our regional biomass resources. The Morris facility will continue to apply innovations and optimize its operations to demonstrate the potential of renewable resources.

III. Conclusion

It is important to realize that the estimates in this report have been made based on one facility at the beginning of start-up and should be used with caution. That said, they are estimates from a brick and mortar facility that has experienced many of the possible difficulties in developing a renewable energy project. The facility was designed as a more stable alternative to counter extremely variable and high natural gas prices during most of the last decade. Estimates were that low cost regional biomass feedstocks would both save the University of Minnesota, Morris money and provide income and job opportunities to a rural county with a declining employment base. Our experience to date is that biomass is considerably more expensive to purchase than early estimates predicted. This, combined with the facility’s difficulties in using unprocessed material, has meant that the actual cost of biomass use has increased several fold over predictions. Even with these added costs, the biomass facility would likely be cost competitive versus natural gas if natural gas had continued its rapid cost increases. Because of the world-wide slump in the economy, natural gas prices have fallen to levels not seen in several years. Therefore, natural gas is less costly then biomass at the present time. However, natural gas prices will likely increase over time and probably become less competitive then biomass.

With increased efficiency and improved technologies, future biomass plants are likely to be able to substantially lower both construction and operational expenses. As a novel facility researching the use of feedstocks known to be difficult to work with, the Morris Biomass Gasification Facility has begun developing the base of knowledge to begin optimizing biomass energy. With this base of information, future facilities will have a starting point to begin implementing new innovations.

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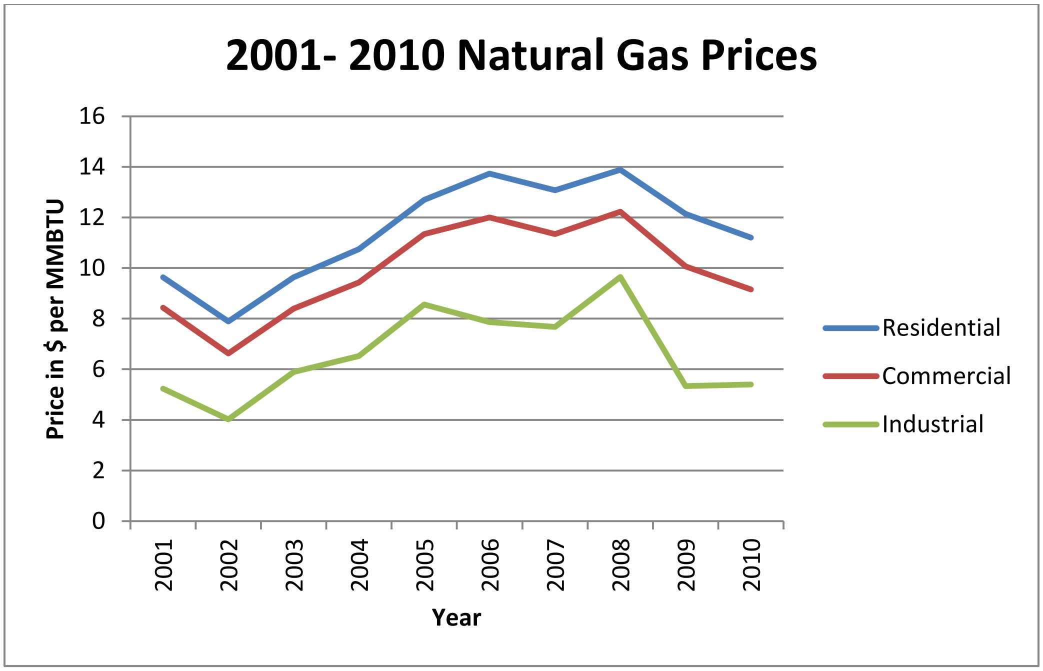

Figure 1. NG prices 2001 to 2010. Data from the US Department of Energy, Energy Information Agency

Table I- Capital Costs

2003 Cost Estimates

Estimated Complete Project		**$**	**5,100,000**

2007 Approved Budget

Building	2030000		
Mechanical and Electrical	3700000		
Gasification equipment	1270000		
Non Construction Costs	1956000		
Total Approved Budget		**$**	**8,900,000**

Costs to date (2011)

Approved Budget	$ 8,900,000
Additional Construction and Start-Up	???

Table II- Labor Costs for Biomass Operations

Predicted Additional Labor For Biomass Operations

Grounds Crew (biomass movement, clean up)		$	1,500
Hours per week	50		
Salary per hour	$ 30.00		
Management and Accounting (Biomass purchasing, QC, Emissions tracking)		$	450
Hours per week	15		
Salary per hour	$ 30.00		
Mechanical Systems & boiler support staff (spread between trades)		$	600
Hours per week	20		
Salary per hour	$ 30.00		
	Per Week	$	2,550
	Total additional Labor Per year	**$**	**132,600**

Table III- Operations and Maintenance For Biomass Plant

Predicted Annualized Auxiliary Equipment Costs

(Equipment for biomass handling logistics)

Telehandler	50,000		
Semi-Truck with walking floor trailer	70,000		
Conveyer	10,000		
Tractor With Bucket Loader	50,000		
(purchase price for used equipment- 10 yr life)	$ 180,000.00		
	Equipment Capital	$	18,000
	Equipment Operational	$	8,000
	Sub-Total	**$**	**26,000**

Predicted Additional Maintenance

(Not including Plant staff labor)

Estimated Total Expenses		$	15,000
Parts / Boiler Cleaning			
Sensors / Filters			
Refractory Maintenance		$	12,000
	Sub-Total	**$**	**27,000**

Additional supplies

NaOH		$	15,000
Water		$	5,000
Electricity			
	Sub-Total	**$**	**20,000**

Total Yearly $ 73,000

Table IV- Fuel Costs

A. Natural Gas Costs

(Based on 2006-2007 data from Brun 2008)

Gross MMBTU	92776
Conversion efficiency	85%
Net MMBTU	78859
Calculated $ per MMBTU (yearly average)	$8.24
Total Delivered NG Cost	$764,692

B. Predicted (Wood) Fuel Costs Using 2003 Biomass Costs

(Based on 2003 feasibility Study and 2006-2007 data above)

2003 Feasibility Study	MMBTU/ton		11.25
	$ per MMBTU		$1.89
	Price per ton		$21.26
2006-7 Data	Net MMBTU		78859
	Net Tons Needed		7169
	Gross Tons Needed (80% conversion rate)		8961.25
	Biomass Costs	$	190,539
	2003 Predicted O and M	$	122,000
	Total Delivered Biomass Costs	$	312,539

Table V- Low Biomass Fuel Cost Scenario

Note: The template is designed so that cells bordered with lines are user entered variables and the cells with a gray background are calculated values.

Current Predicted Biomass Fuel and Associated Costs (2011)

Expected Biomass Use (Tons per year) 9000

			Per Ton Costs
Purchase costs			$ 60.00
Processing Costs			$5.00
Resizing	$5.00		
Densification	$0.00		
Storage Costs			$ 4.02
Indoor Storage (high value densified product)		$ -	
Tons on hand	0		
lbs. on hand	0		
lbs. per cu. ft.	35		
cu. Ft.	0		
Pile height (ft)	8		
sq. ft.	0		
Rental $ sq. ft. yr.	$ 3.00		
Total yearly cost	$ -		
Cost per ton used	$ -		
Outdoor Storage (low value densified product)		$ 0.33	
Acres needed	10		
Land Value*	$ 300.00		
Total cost for site	$ 3,000		
Storage loss		$ 3.69	
Percent per month	1%		
Average Storage tim	4		
%loss	0.061520151		
$ value	$ 3.69		
		Total price per ton	**$ 69.02**

Corresponding Yearly Fuel Costs

Net MMBTU	78859	(from 2006-2007 data)		
BTU/lb	6500			
BTU per ton	13000000	Total price per Gross MMBTU	$	5.31
MMBTU per ton	13	Calculated Gross MMBTUs to Replace NG		98574
Conversion Efficiency	80%	**Annual Biomass Fuel Costs at 2006-2007 usage**	**$**	**523,385**

Table VI- Mid-Range Biomass Fuel Cost Scenario

Note: The template is designed so that cells bordered with lines are user entered variables and the cells with a gray background are calculated values.

Current Predicted Biomass Fuel and Associated Costs (2011)

Expected Biomass Use (Tons per year) 9000

			Per Ton Costs
Purchase Costs			$ 65.00
Processing Costs			$20.00
Resizing	$5.00		
Densification	$15.00		
Storage Costs			$ 4.81
Indoor Storage (high value densified product)		$ 0.48	
Tons on hand	200		
lbs. on hand	400000		
lbs. per cu. ft.	35		
cu. ft.	11428.57143		
Pile height (ft)	8		
sq. ft.	1428.571429		
Rental $ sq. ft. yr.	$ 3.00		
Total yearly cost	$ 4,286		
Cost per ton used	$ 0.48		
Outdoor Storage (low value densified product)		$ 0.33	
Acres needed	10		
Land Value*	$ 300.00		
Total cost for site	$ 3,000		
Storage loss		$ 4.00	
Percent per month	1%		
Average Storage tim	4		
%loss	0.061520151		
$ value	$ 4.00		
		Total price per ton	**$ 89.81**

Corresponding Yearly Fuel Costs

Net MMBTU	78859	(from 2006-2007 data)		
BTU/lb	6500			
BTU per ton	13000000	Total price per Gross MMBTU	$	6.91
MMBTU per ton	13	Calculated Gross MMBTUs to Replace NG		98574
Conversion Efficency	80%	**Annual Biomass Fuel Costs at 2006-2007 usage**	**$**	**680,980**

Table VII- High Biomass Fuel Cost Scenario

Note: The template is designed so that cells bordered with lines are user entered variables and the cells with a gray background are calculated values.

Current Predicted Biomass Fuel and Associated Costs (2011)

Expected Biomass Use (Tons per year) 9000

			Per Ton Costs
Purchase Costs			$ 75.00
Processing Costs			$50.00
Resizing	$15.00		
Densification	$35.00		
Storage Costs			$ 5.90
Indoor Storage (high value densified product)		$ 0.95	
Tons on hand	400		
lbs. on hand	800000		
lbs. per cu. ft.	35		
cu. ft.	22857.14286		
Pile height (ft)	8		
sq. ft.	2857.142857		
Rental $ sq. ft. yr.	$ 3.00		
Total yearly cost	$ 8,571		
Cost per ton used	$ 0.95		
Outdoor Storage (low value densified product)		$ 0.33	
Acres needed	10		
Land Value*	$ 300.00		
Total cost for site	$ 3,000		
Storage loss		$ 4.61	
Percent per month	1%		
Average Storage tim	4		
%loss	0.061520151		
$ value	$ 4.61		
		Total price per ton	**$ 130.90**

Corresponding Yearly Fuel Costs

Net MMBTU	78859	(from 2006-2007 data)	
BTU/lb	6500		
BTU per ton	13000000	Total price per Gross MMBTU	$ 10.07
MMBTU per ton	13	Calculated Gross MMBTUs to Replace NG	98574
Conversion Efficency	80%	**Annual Biomass Fuel Costs at 2006-2007 usage**	**$ 992,560**

Table VIII- Total Fuel Cost Comparisons

Biomass Cost Models*

	Low	Mid	High
Estimated Yearly Biomass Cost	$ 523,385	$ 680,980	$ 992,560
Estimated Labor	$ 132,600	$ 132,600	$ 132,600
Estimated O & M	$ 73,000	$ 73,000	$ 73,000
Total Yearly Cost	**$ 728,985**	**$ 886,580**	**$ 1,198,160**

Natural Gas Cost Models[1,2,3]

	Low	Average	High
Natural Gas Price	$ 4.485	$ 7.082	$ 10.115
2006-2007 Gross MMBTU	92776	92776	92776
Total Yearly Cost	**$ 416,098**	**$ 657,036**	**$ 938,424**

[1] 2006-2007 Consumption data used

[2] Natural gas prices estimated using DOE Energy Information Administration Data with estimated regional delivery charge. (see text for description)

[3] Data is high, low, and average annual price for the 10 year period 2001 to 2010 from EIA

Study 2: Regional Economic Impact Analysis

1 Regional Economic Impact Analysis of the Biomass Gasification Plant at the University of Minnesota, Morris

Purpose: The purpose of this report is to evaluate the local economic impacts of the biomass gasification plant at the University of Minnesota, Morris (UMM).

Background: In the 2007-2008 State of Minnesota bonding bill, funds were approved for the construction of a novel biomass gasification plant for the University of Minnesota, Morris, to be coupled with a high-pressure steam boiler. The primary feed stock was proposed to consist of crop residues (specifically corn stover) harvested from local farms. The plant will initially displace an estimated 80% of the steam heating load for the rural campus in west central Minnesota. With the addition of an absorption chiller (summer, 2010) the plant would have the potential to meet the campus' entire chilled water (a/c) load in summer (previously serviced by electrical chillers).[1] The new plant largely replaces a dual-fuel system (natural gas and home heating oil) for low-pressure steam, although these latter units remain on-line for back-up and peak-load periods. This new plant is uniquely situated as both a research and an operations platform. Advanced emissions monitoring capability, for example, enables research to proceed on alternative crops.

Profile and Assumptions: The annual UMM MMBTU purchases (natural gas, with an occasional supplement of fuel oil) for the boiler plant over the past five years average $100,874. The existing boilers operate at approximately 82.5% combustion efficiency, implying captured MMBTUs of 80,699. To replace 80% of the thermal load with corn stover-derived BTUs (@7540 BTU/lb), assuming 80% conversion efficiency in the gasifier and 86.5% thermal efficiency in the new high pressure boiler, will require 6,417 tons annually of feedstock. Lazarus (2008) estimates a break-even price for corn stover of $50/ton, covering the additional labor & interest costs ($3/ton), machinery costs to shred, rake, bale and transport 25 miles ($27/ton) and fertilizer replacement costs ($20/ton). Lazarus estimates a market price of $60/ton (leaving $10/ton profit for the grower). Toso (2008) estimates the incremental labor and materials handling expenses at the University to be $19.41/ton.

Methodology: We employ standard input-output analysis, using county-level (and, subsequently, state-level) input-output data from the Minnesota IMPLAN Group, Inc.[2] We use the vector of incremental cost allocation

[1]We do not model the effect of the substitution from electricity purchases to biomass purchases in this exercise. Nor do we model the combined heat and power efficiencies realized by the installation of a backpressure turbine behind the high-pressure steam boiler. This exercise is strictly limited to understanding the substitution from one to another source of thermal energy for the purpose of meeting campus heating and domestic hot water requirements.

[2]For a basic description of input-output modeling, see http://en.wikipedia.org/wiki/Input-output_model. For a description of the IMPLAN model and database construction, see http://implan.com/v3/

described above. IMPLAN is a non-survey input/output modeling program that utilizes a national set of structural matrices compiled out of state level, value added data extracted from the Bureau of Economic Analysis (BEA) reports for the purpose of economic impact analysis. IMPLAN allocates estimates for state total gross outputs across counties according to each county's employment earnings, which are calculated using data from the BEA County Business Patterns Reports in order to derive national models that represent the average condition for a particular industry. For more details, see the IMPLAN user's manual, available from the Minnesota IMPLAN Group: www.implan.com

IMPLAN models distinguish three types of effects:

- *Direct effects* represent "the impacts (e.g. change in employment) for the expenditures and/or production values specified as direct final demand changes."
- *Indirect effects* represent "the impacts (e.g. change in employment) caused by the iteration of industries purchasing from industries resulting from the direct final demand changes."
- *Induced effects* represent the impacts (e.g. change in employment) on all local industries caused by the expenditures of new household income generated by the direct and indirect effects of direct final demand changes.

Furthermore, IMPLAN allows the analyst to break out results according to Value Added (Labor, Profits, Rents, and Taxes), Employment, and Gross Output.

2 Stevens County Economic Impact Simulation #1

In our first simulation we model natural gas prices at $10/MMBTU. We assume 80% of the campus thermal load is replaced by biomass. The resulting savings are entered as a separate impact.[3] We assign the vector of impacts described above according to Table 1, using IMPLAN industries and final demand vectors:

[3] Effectively this imposes a budget constraint on the University. When savings on fuel inputs are realized, University spending is assumed to expand consequently, according to the spending vector in sector 12002 (*State & Local Government -- Education*).

Table 1: Assignment of initial impacts to IMPLAN industries and institutions

Input	Cost per ton	Total change	IMPLAN Sector	IMPLAN Sector Description
On-farm labor	$3	$19,251	1004	Households $25-$35K
Natural gas expenditures	n/a	-$806,995	31	Natural gas distribution
On-farm machinery	$13.33	$85,538	257	Farm machinery & equipment manufacturing
Farm machinery maintenance	$13.66	$87,656	485	Commercial machinery maintenance & repair
Fertilizer - N	$10	$64,170	156	Nitrogenous fertilizer manufacturing
Fertilizer - P	$10	$64,170	157	Phosphatic fertilizer manufacturing
UMM Employment (Materials handling)	$19.41	$124,553	10006	Households $50-$75K
Farmer VA	$10	$64,170	10008	Households $100-$150K
University savings	n/a	$264,947 [4]	12002	State & local government -- education

Simulation 1 Results:

Value Added: Table 2 presents the additional value added that accrues in the county as a result of the changes described above.

Table 2: Value Added ($10/MMBTU NG prices; 6417 tons biomass annually)

	Direct	Indirect	Induced	TOTAL
Employee Compensation	308,257	8,076	33,841	350,174
Proprietors Income	84,238	1,106	3,851	89,195
Rents & Other Property Type Income	52,745	3,782	27,987	84,514
Indirect Business Taxes	92,383	1,400	9,089	102,872
TOTAL	537,623	14,364	74,768	626,755

[4] Formula: (incremental biomass expenditures) - (reduced natural gas expenditures).

Taking into consideration the direct, indirect, and induced effects, the changes in final demand associated with the new biomass facility generate (annually) $626,755 in *additional* income in Stevens County. These are operations-phase impacts, exclusive of construction. Table 3 rank orders the top 10 industries according to the greatest total impact on sales in the county.

Table 3: Top 10 Output-Affected Industries

IMPLAN Sector	IMPLAN Sector Description	Total Sales Impact ($1000s)
485	Commercial machinery repair and maintenance	70.7
509	Owner-occupied dwellings	46.3
481	Food services and drinking places	21.4
390	Wholesale trade	20.6
467	Hospitals	19.0
465	Offices of physicians, dentists and other health	10.3
430	Monetary authorities and depository credit intermediaries	9.9
401	Motor vehicle and parts dealers	9.2
405	Food and beverage stores	8.7

Employment: The simulation described above yields employment impacts as per Table 4.

Table 4: Employment Impacts ($10/MMBTU NG prices)

	Direct	Indirect	Induced	TOTAL
$10/MMBTU Stevens County Simulation	8.7	.3	1.6	10.7

Simulations results indicate 10.7 additional jobs in Stevens County as a result of the new biomass plant and the consequent cash flows. Again, these are operations phase results, post-construction.

3 Stevens County Economic Impact Simulation #2

In our second simulation we use a benchmark natural gas price of $5/MMBTU (i.e. 50% lower than in the first simulation). In fact, as of this writing (August, 2010), $5/MMBTU is very close to the actual market price -- although that price has been over three times higher at various points during the past 5 years.

Under this cheap natural gas scenario, the University actually spends extra on biomass fuels and handling, which requires cutbacks elsewhere in its budget (see footnote 3). Table 5 summarizes the value added effects that result. Here we see that the impacts are smaller by about one order of magnitude, compared with the previous simulation. While the University must cut back elsewhere by more than its new direct value added purchases (hiring of materials handlers), there is still a small positive effect on the regional economy, because a large flow of spending previously leaking directly into "imports" has been diverted to "domestic" production of biomass, as well as "domestic" value added (wages). While this is a somewhat expensive outcome for the University, it remains a net positive for the region.[5]

Table 5: Value Added ($10/MMBTU NG prices)

	Direct	Indirect	Induced	TOTAL
Employee Compensation	67,483	7,483	5,359	80,325
Proprietors Income	83,302	946	610	84,858
Rents & Other Property Type Income	25,311	3,496	4,435	33,242
Indirect Business Taxes	8,734	1,305	1,440	11,479
TOTAL	184,830	13,230	11,844	209,904

[5] It should be clarified that the comparison being undertaken here involves the county-wide economic impact of having the biomass system in place, versus not having it in place. We are asking here "what is the economic impact of having and operating the biomass plant, at various levels of natural gas prices?" The budget constraint described in footnote 3 amounts to assuming that the budget is fixed at an amount necessary to meet thermal demand with natural gas. If the price of natural gas is low enough that forces the University to adopt austerity measures, assuming it continues to use the relatively more expensive biomass fuel. An alternative modeling approach would have been to assume that the heating plant is operated as a true dual- (or tri-) fuel operation, with a fixed annual budget for therms. In that scenario, a sufficient decrease in natural gas prices causes a switch away from biomass, and results in direct "University savings" (compared with the fixed budget for therms). Since the emphasis of this study is on the relative merits of biomass vs. natural gas therms, rather than on the merits of low energy prices *per se*, the former approach was chosen.

Table 6 reports the employment impacts from the second simulation. Here the University's dissavings associated with the project actually reduce its expenditures elsewhere, providing an anti-stimulus along side the original stimulus. As a consequences, net job creation associated with the project falls from 10.7 to 3.1.

Table 6: Employment Impacts

	Direct	Indirect	Induced	TOTAL
$5/MMBTU Stevens County Simulation	2.5	.3	.3	3.1

4 State of Minnesota Economic Impact Simulation Set-up

In this section, we report the results of a simulation of the input-output model for a broader region: the entire State of Minnesota. Since the local county is small and un-diversified it suggests that most of the spending flows induced by the new project will in fact leak out of the county rapidly. The purchase of new bailing equipment, for example, may leave a small residual income effect (for example from the sales commission of the retailer), but the larger part of the value added will accrue at the location of the manufacturing plant, outside the county. When the focus is on the State of Minnesota as a whole, the "import" coefficients will in general be smaller, so it might be expected that the multipliers will be larger.

Here we report our findings from simulating the change in final demand from Table 1 in a State of Minnesota input-output model (again assuming $10/MMBTU natural gas). In fact, the reasoning in the previous paragraph is correct, in a qualified sense. As it turns out, the natural gas industry has an important presence in the state -- particularly at the distribution and pipeline services levels -- even though it is not present in Stevens County. The diversion of expenditures away from natural gas and towards biomass feedstocks is a switch away from "imports" and onto "domestic production" when the capture area is Stevens County; however, when the entire state is modeled, the switch amounts to a switch away from one industry with a strong domestic component in production, and towards one with a somewhat lower domestic production component. The $806,995 reduction in natural gas spending has almost no impact on economic activity in Stevens County, but it has a significant impact at the state level.

Table 7 shows that the total value added at the state level has risen to $861,804, as compared with $626,755 at the county level. The jobs picture is somewhat improved also: at the state level employment expands to 14.9 jobs, as compared with 10.7 at the county level.

Table 7: State-wide Economic Impacts on Value Added

	Direct	Indirect	Induced	TOTAL
Employee Compensation	408,672	16,673	173,302	598,647
Proprietors Income	87,020	1,102	16,973	105,095
Rents & Other Property Type Income	28,590	8,570	88,835	125,995
Indirect Business Taxes	1,500	2,580	27,987	32,067
TOTAL	525,782	28,925	307,097	861,804

Table 8: Statewide Employment Impacts

	Direct	Indirect	Induced	TOTAL
$10/MMBTU State-wide Simulation	9.8	0.4	4.7	14.9

5 Concluding Observations

We have undertaken an input-output analysis of the economic impact of the new biomass gasifier at the University of Minnesota, Morris. Principal findings are that at the county level, the annual net effect on value added and jobs are respectively, $626,755, and 10.7 permanent jobs for the operations phase of the project, assuming a natural gas price of $10/MMBTU. As we aggregate up to the state level, the greater diversity of industries leads to smaller leakages into "imports;" however, the losses to the natural gas industry (and its suppliers) are brought into the capture area. The net economic impacts at the state level are somewhat larger: $861,804 in new value added, and 14.9 jobs. Finally, when we consider gas prices at their current, historically low levels, the cost savings to the University are reversed. Nevertheless, county impacts show a $209,904 increase of local value added, as well as the addition of 3.1 jobs.

Some cautionary notes are necessary at this point:

- The analysis does not compare costs and benefits, either in financial or environmental terms.[6]
- The capital costs of the project were largely underwritten by the state legislature, and are not considered in the analysis here.

[6] A subsequent study estimates economics from the narrower internal rate of return perspective.

- At the time of this writing (August, 2010), a reformulated fuel mixture is under consideration, involving a blend of prairie grasses and corn stover. The economics of this mixture have not been analyzed here.
- At the time of this writing, densification of the feedstock is under consideration. The economics of this process have not been analyzed here.

The absolute size of the estimated impacts is quite small, but so is the absolute size of this pilot project. Certainly the availability of appropriate crop residues in the state is sufficient to scale this project up by at least a factor of 500 -- at which point the analysis here suggests statewide job creation numbers in the thousands. Nor does heating and cooling demand provide a binding constraint. In fact it may well be the case that economies of scale in collection and materials handling lead to significant cost reductions.

6 Bibliography

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Slide 3-2010 Short Course -Biomass Econ1

Project Detail

Cost Estimate:

Building	$2,030,000
Mechanical and Electrical Systems	3,700,000
Gasification Equipment	1,270,000
Non Construction Costs	1,956,000
Total	**$8,956,000**

Funding:

	Original Total	Increase	Revised Total
Legislative Appropriation 2005	$4,000,000		$4,000,000
IREE (Initiative for Renewable Energy & the Environment)	1,000,000		1,000,000
University Debt	1,000,000		1,000,000
University of Minnesota Morris		$600,000	600,000
Corn Growers Association		20,000	20,000
AURI (Agricultural Utilization Research Institute)		5,000	5,000
USDA/DOE Grant (Equipment)		631,000	631,000
Institutional Resources		1,700,000	1,700,000
Total	**$6,000,000**	**$2,956,000**	**$8,956,000**

Capital Budget Amendment — June 2007

University of Minnesota