Using Biomass to Supplement Natural Gas for Hydronic Heating in a Greenhouse Complex

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ABSTRACT

In 2003, the Industrial Assessment Center at Mississippi State University performed an energy assessment for Natchez Trace Greenhouses. A recommendation made to the facility to reduce natural gas usage was to replace the existing natural gas boilers with bio-mass boilers that burn biomass fuels for use in a hydronic heating system.

Burning wood shavings and/or other bio-mass fuels was recommended as a viable fuel alternative to offset the rising price of natural gas. Wood chips with an average energy cost of $1.64/MMBtu (from 2004-2007) are readily available from a local sawmill. Grain corn with an energy cost of $5.81.MMBtu in 2003/2004 can be purchased locally. In 2003/2004, the facility was paying $5.78/MMBtu for natural gas and anticipated a significant increase in the price of natural gas.

Partial implementation in 2004-2005 and rapidly escalating natural gas prices convinced the owner to supplement natural gas with wood shavings and corn to heat the greenhouses. Three new 40-hp fire-tube boilers were installed and existing 40-hp natural gas boiler was converted to burn biomass fuels. Based on the assessment, the facility was able to obtain loans from the State of Mississippi and the U. S. Department of Agriculture to implement the recommendation.

During the winter of 2005-2006, the new fire-tube and the retrofitted boilers using biomass fuels were fully operational. Planer wood shavings, corn, and wood pellets are the fuels being considered for burning. Future fuel possibilities are briquettes made of cottonseed hulls. The proposed paper will analyze the fuel savings realized by the facility, the cost of implementation, the savings, the added maintenance and operating costs, and the effects of using biomass as fuel.

Introduction

During May 2003, the Mississippi State University Industrial Assessment Center (MSU IAC) performed an industrial energy assessment for Natchez Trace Greenhouses located in Kosciusko, Mississippi. One of the assessment recommendations implemented at the facility was to heat the greenhouses by replacing the existing natural gas boilers with fire-tube (fire-box) boilers that use bio-mass fuels such as wood shavings and corn to reduce natural gas consumption. The availability of corn, as well as, wood shavings from a local sawmill made the installation of bio-mass boilers economically attractive. However, the owner of the greenhouses is competing with a local paper mill for the wood shavings.

Company Profile

Natchez Trace Greenhouses cultivates a variety of annual and perennial ornamental plants from seedlings that mature in greenhouses. The facility sits on 4 acres consisting of greenhouses totaling 230,062 square feet. The greenhouses are constructed with metal and wood frames.

The coverings of the buildings include double polyethylene, corrugated plastic, and glass. Each greenhouse has different heating requirements depending on the type of plants in the greenhouse. In 2003 five natural gas boilers totaling 440 hp produced hot water that was circulated through fan coil units to heat the greenhouses. The boilers typically operate part of the month of September and all of the months of October through March and part of April.

Implementation

In 2003 the owner of the facility began installation of three new 40-hp bio-mass boilers and the retrofitting of a fourth natural gas boiler with the necessary equipment to burn bio-mass fuel. By December 2005, the retrofitting and installation process of the biomass system was completed. Figure 1 illustrates the layout of the greenhouses with the locations of the natural gas and bio-mass boilers and the areas they heat. Figure 2 is a photograph of a newly installed and operational 40-hp fire-tube boiler that is located outside the new boiler room. The installation and retrofitting of the bio-mass boilers from 2003 through 2005 reduced the consumption of natural gas used to heat the greenhouses. This proved to be timely, given the significant escalations in energy costs in Mississippi in 2005 due to Hurricane Katrina in August of 2005. Figure 3 depicts the cost to heat the greenhouses with natural gas during the heating months of September through April from 2001-2007.

Figure 1. Heating Systems for the Greenhouses

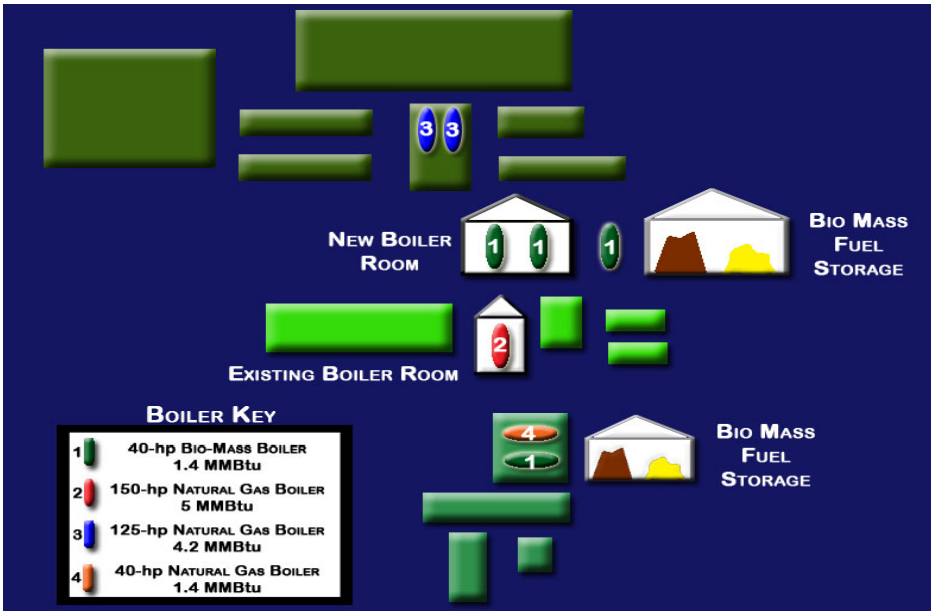
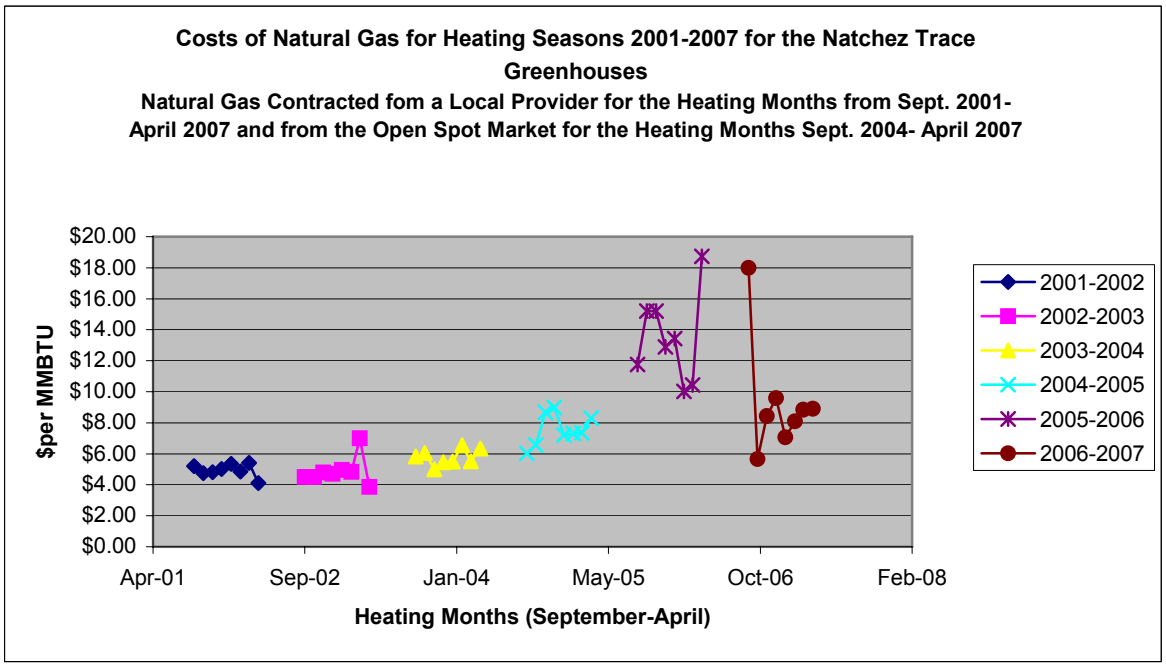


Figure 2. A Newly Installed and Operational 40-HP Bio-Mass Boiler

Figure 3. Costs of Natural Gas from 2001-2007 for Natchez Trace Greenhouses



Future plans are to retrofit the150-hp natural gas boiler with equipment to burn bio-mass. The two 125-hp natural gas boilers located in one of the greenhouses will continue to be fueled by natural gas. The three newly installed bio-mass boilers pre-heat the water, which then flows to the 125-hp natural gas boilers where it is heated to its operating temperature.

Fuel Used in the Bio-Mass Boilers

The bio-mass boilers burn planer wood shavings and corn for fuel. Wood shavings are purchased and delivered in twenty-ton loads every three to four days from a local sawmill about 30 miles away, and corn is purchased and delivered in 2,500- bushel-loads as needed from a broker in the area. At the new boiler site, the bio-mass is stored under a covered area that can be seen in Figure 4. The bio-mass is conveyed into two storage tanks depicted in Figure 5. Each tank holds eight to ten tons. The wood shavings and corn are taken from the storage tanks, mixed in a bin, and carried by a screw conveyor into the bio-mass boilers. The fuel mixture contains approximately seventy percent wood shavings and thirty percent corn. The average moisture content of the wood shavings is seven percent. In 2003 the owner of the facility considered burning wood pellets at $6.25/MMBtu with a heating value of 8000 Btu/lb but the fuel was not commercially available geographically. The use of wood pellets will be reviewed at a later time. The owner of the greenhouses reduced the use of corn as a fuel in 2006 with the price of corn at $9.90 per MMBtu exceeding the price of natural gas at $9.32 per MMBtu. Future plans are to burn briquettes made of cotton seed hulls that have a Btu output equivalent to corn.

Table 1 presents the cost of wood shavings, corn, and natural gas per MMBtu and the cost of wood shavings per ton and corn per bushel for the years 2004-2007. From 2004 through 2007 wood shavings have averaged costing the owner $26/ton. In the past three years the owner paid the following for corn: $2.70/bushuel in 2004, $3.03/bushel in 2005, and $4.60/bushel in 2006. From 2004-2007, Natchez Trace Greenhouses burned bio-mass fuel along with natural gas to heat the greenhouses.

Table 1. Costs of Wood, Corn and Natural Gas

	Wood Shavings *Average Cost of Wood per MMBtu	**Corn** *Average Cost of Corn per MMBtu	**Natural Gas** Average Cost of Natural Gas per MMBtu (Purchased on the open spot market)
2004-2005	$1.56	$5.81	$7.46
2005-2006	$1.69	$6.52	$13.46
2006-2007	$1.69	$9.90	$10.41

*The heating values used to determine the cost per MMBtu for wood shavings and corn are 8,000 Btu/lb and 8,300 Btu/lb, respectively.

Figure 4. Bio-Mass Storage Area

Figure 5. Bio-Mass Storage Tanks

Each of the 40-hp bio-mass boilers consumes approximately 220 lb of fuel per hour fully loaded. The typical hot water temperature output from the bio-mass boilers is 145 °F. The bio-mass boilers run at atmospheric pressure with an efficiency of approximately seventy percent. Table 2 lists the amounts of wood shavings and corn purchased from 2004 through 2007. In the 2003-2004 heating season, all of the wood shavings and corn purchased were burned to heat the greenhouses. In the 2005-2006 season, two-thirds of the wood shavings and ninety-five percent of the corn purchased were burned. Table 3 shows the amount of bio-mass burned to supplement the facilities natural gas usage from 2004-2007.

Table 2. Amounts of Bio-Mass Purchased

	Wood Shavings	**Corn**
	MMBtu's Purchased	MMBtu's Purchased
2004-2005	2,982	1,704
2005-2006	10,155	4,964
2006-2007	7,785	2,654

Table 3. Natural Gas and Bio-Mass Fuel Usage

	Natural Gas	**Wood Shavings**	**Corn**	
	MMBtu Usage	MMBtu Usage	MMBtu Usage	Total MMBtu Usage
2001-2002	21,558	N/A	N/A	21,558
2002-2003	20,869	N/A	N/A	20,869
2003-2004	18,565	N/A	N/A	18,565
2004-2005	13,218	2982	1704	17,904
2005-2006	2,233	9,898	4790	16,821
2006-2007	9,662	7,785	2,654	20,101

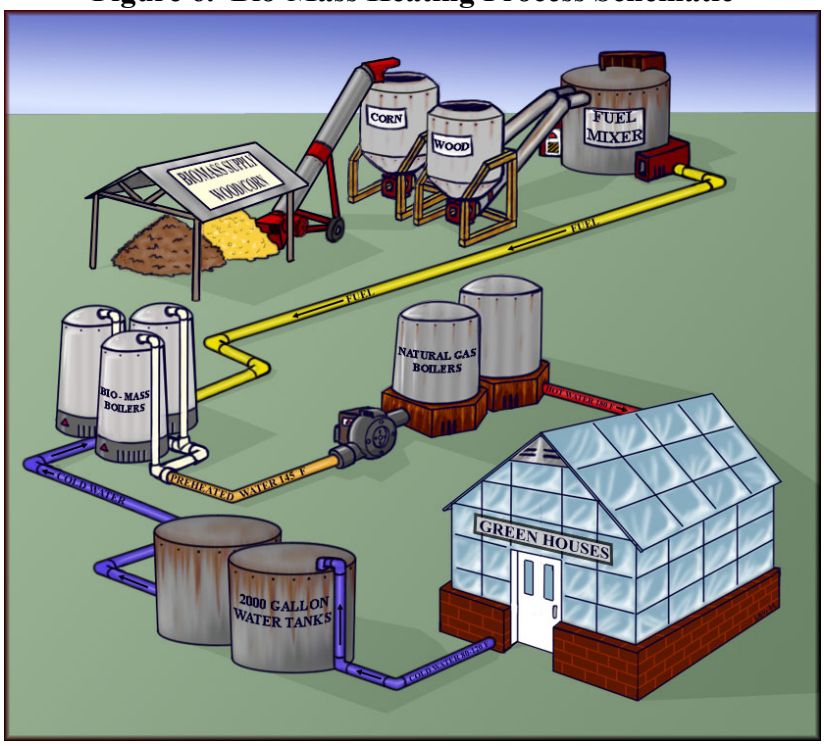
Natchez Trace Greenhouses currently has 20.4 MMBtu of boiler capacity. The bio-mass boilers account for 6.6 MMBtu of the capacity that is used to pre-heat water. The remaining 13.8 MMBtu of boiler capacity is accounted for by natural gas boilers, which are supplemented by the bio-mass boilers. In terms of meeting the Mississippi Environmental Protection Agency (EPA) guidelines, as long as the total facility boiler capacity burning bio-mass does not exceed 10 MMBtu/hr, the facility does not need to apply for an environmental permit.

Implementation Costs

The facility was able to obtain loans of $135,000 from the Land, Waste, and Timber Board of the State of Mississippi, $40,000 from the United States Department of Agriculture, and $40,000 in kind for materials and parts was supplied by the facility. The industrial assessment performed by the Mississippi State University IAC aided the facility in obtaining the loans by defining the needs of the project and the cost to implement the new system as well as estimating the cost savings that could be obtained by the facility.

The installation of the three new bio-mass boilers account for the largest percentage of the total implementation cost of the system. Figure 6 illustrates the new boiler area with the three newly installed bio-mass boilers. The bio-mass fuel, which is stored under a covered area, is transferred to two storage silos, one for corn and the other for wood shavings. Both bio-mass products are then mixed in the fuel mixer and transferred to the bio-mass boilers. When the system is first brought on line, the exit water has an average temperature of 80˚F. However, after the system has been running for a few hours, the exit water has an average temperature of 120˚F. The bio-mass boilers pre-heats the exit water to 145˚F. If the nighttime temperature is above 45˚F then the temperature of the water coming from the bio-mass boiler is sufficient to heat the greenhouses. If the nighttime temperature is below 45˚F then the 145˚F water from the bio-mass boilers is heated to 180˚F by the two 125-hp natural gas boilers.

Figure 6. Bio-Mass Heating Process Schematic



The actual implementation cost of the new system was approximately $215,000 for the purchase of three new bio-mass boilers, the retrofitting of one natural gas boiler, the material handling/storage equipment, water storage systems, pump/piping system (steel pipes), parts, and materials. The breakdown of the costs is in Table 4.

Table 4. Implementation Costs

Retrofit the 40-hp Boiler	$5,000
Purchase of Three New Bio-Mass boilers	$102,000
Material Handling/Storage Equipment, Water Storage Systems, and Pump/Piping Systems	$68,000
In-Kind Material and Parts	$40,000

Cost Savings

Natchez Trace Greenhouses contracted natural gas from a local provider for the heating seasons 2001-2004. From 2004-2007 the facility purchased natural gas off the spot market. In 2005, Hurricane Katrina had a direct impact on the rise in price of natural gas. As a result, the facility paid double the previous year's average natural gas price to heat the greenhouses.

In 2004 the facility began to use bio-mass to help heat the greenhouses in the first phase when two of the three bio-mass boilers were installed. Two additional bio-fuel boilers (a new one and a retrofitted one) were installed and operational by the 2005 heating season. When available, burning wood shavings for fuel is more economical for the facility than burning natural gas. However, the price of natural gas stabilized over the previous season and burning corn became less economical than natural gas. Table 5 gives a complete list of the seasonal fuel usages and corresponding fuel heating costs.

Bio-mass fuel was used to supplement natural gas usage for the entire 2005-2006 and 2006-2007 seasons. If natural gas alone had been used during 2005-2006 and 2006-2007, the cost to heat the facility would have been $213,145 and $168,280 respectively as shown in Table 6. However, the actual heating costs for 2005-2006 and 2006-2007 seasons were $76,353 and $118,748 respectively. This resulted in a savings of $136,792 for the 2005-2006 season and $49,532 for the 2006-2007 season. Table 7 outlines the savings per year attained by burning bio-mass to reduce natural gas consumption.

Maintenance and Emissions

Maintenance issues for the boilers and the burning of the bio-mass fuel has not posed any real problems. However, vigilance is required when operating the bio-mass boilers. The Mississippi Environmental Protection Agency (EPA) issued an opinion stating that as long as the total facility boiler capacity does not exceed 10 MMBtu/hr, the facility does not need to apply for an environmental permit. EPA has confirmed that the new and retrofit fire-box boilers operate under that capacity.

Table 5. Bio-Mass and Natural Gas Heating Costs

	Natural Gas		Wood Shavings		Corn		**Total Costs to Heat Greenhouses Using All Three Fuels**
	Total MMBtu Usage	Total Costs	Total MMBtu Usage	Total Costs	Total MMBtu Usage	Total Costs	
2001-2002	21,558	$107,990	N/A	N/A	N/A	N/A	**$107,990**
2002-2003	20,869	$105,547	N/A	N/A	N/A	N/A	**$105,547**
2003-2004	18,565	$106,786	N/A	N/A	N/A	N/A	**$106,786**
2004-2005	13,128	$95,062	2982	$4660	1704	$9,901	**$109,623**
2005-2006	2,233	$28,401	9,898	$16,703	4790	$31,226	**$76,353**
2006-2007	9662	$79,346	7,785	$13,137	2,654	$26,265	**$118,748**

Table 6. Heating Cost if Only Using Natural Gas

2005-2006	MMBtu Usage	Cost of Natural Gas Per MMBtu	Total Cost
September	35	$11.75	$411
October	1522	$15.21	$23,146
November	2670	$15.21	$40,606
December	3684	$12.90	$47,528
January	2932	$13.42	$39,349
February	3774	$10.03	$37,857
March	2278	$10.43	$23,760
April	26	$18.75	$488
Total for 2005-2006			**$213,145**
2006-2007	MMBtu Usage	Cost of Natural Gas Per MMBtu	Total Cost
September	366	$17.99	$6,584
October	1331	$5.66	$7,533
November	3411	$8.42	$28,721
December	3568	$9.58	$34,181
January	3958	$7.07	$27,912
February	3816	$8.09	$30,871
March	2045	$8.84	$18,078
April	1616	$8.91	$14,399
Total for 2006-2007			**$168,280**

Table 7. Cost Savings and Payback per Year

	Potential Seasonal Cost to Heat Greenhouses Using Natural Gas Only	Actual Seasonal Cost to Heat Greenhouses Using Natural Gas and Bio- Fuels	Seasonal Savings
2004-2005	$169,019	$109,623	$59,396
2005-2006	$213,145	$76,353	$136,792
2006-2007	$168,280	$118,748	$49,532
Total Savings			**$245,720**

Conclusion

The decision to install three new bio-mass boilers and retrofit another natural gas boiler to burn biomass fuels has positively impacted the operational costs of Natchez Trace Greenhouses. The facility avoided a sharp increase in the cost of natural gas directly after Hurricane Katrina that caused many other businesses in the region to shut down. The savings produced by the bio-mass boiler system in the 2005-2006 season amounted to $136,792, which is approximately 60% of the implementation cost of the system. Since implementation, the savings accumulated from burning bio-mass to supplement natural gas usage have resulted in an overall savings of more than $245,000. The cost of natural gas will continue to increase due to inflation. Therefore, the bio-mass boiler system implemented at Natchez Trace Greenhouses will continue to save the facility valuable revenue that will ensure it will maintain the required capital to stay in business.