



## The University of Iowa Biomass Fuel Project Supporting Materials

The University of Iowa Biomass Fuel Project Description .....	2
Brief statement of program and results .....	2
Institutional and environmental benefits .....	2
Innovation and creativity .....	3
Portability and sustainability .....	3
Management commitment and employee involvement .....	3
Documentation .....	4
Conclusion .....	4
Carbon Dioxide Reductions and Coal Displacement.....	4
Oat Hull Fuel Description .....	5
Emissions Stack Testing Results .....	7
Purchased Energy Discussion .....	9
Circulating Fluidized Bed Boiler Discussion .....	11
Awards .....	14
Iowa Governor’s Environmental Excellence Awards.....	14
The APPA Effective and Innovative Practices Award .....	15
Chicago Climate Exchange.....	16

## **The University of Iowa Biomass Fuel Project Description**

### **Brief statement of program and results**

Using biomass fuel in its circulating fluidized bed (CFB) boiler, The University of Iowa (UI) Power Plant pioneered a new green energy source that saves hundreds of thousands of dollars in fuel costs annually, and utilizes a renewable waste product.

When the Quaker Oats Company, located approximately 20 miles from the UI, approached the UI Power Plant about bioenergy, it was searching for a market for Resifil, a processed oat hull product it had produced for 80 years. The UI Power Plant was willing to test the product in its circulating fluidized bed boiler. After the test yielded intriguing, but mixed results, the UI-Quaker team decided to try using the unprocessed oat hulls. The feather-weight oat hulls required special materials handling solutions, boiler control system modifications, and new procedures to make this fuel work as a viable long-term source of energy for UI.

The successful effort by the university-industry partnership captured the attention of peer institutions across the country, garnered two awards from Iowa's governor, is applauded by sustainability advocates, and is recognized as a dramatic example of how higher education facilities management can play a key role in enhancing efforts to generate economic development.

### **Institutional and environmental benefits**

The Biomass Fuel Project has been an exciting opportunity for UI to partner with a local industry, reduce fuel costs, reduce greenhouse gas emissions, and utilize a renewable waste product as a resource for Iowa.

The institution is realizing an annual cost saving of over one-half million dollars through the use of oat hulls in place of 25,000-35,000 tons of coal. An oat hull is the outer shell of an oat grain that remains after the soft, protein contain core has been removed by milling the grain. Adding oat hulls to the fuel mix significantly reduces the amount of regulated air pollutants.

In 2004, the projected reduction in green house gas emissions enabled UI to join the Chicago Climate Exchange, a green house gas trading pilot program for emission sources and offset projects.

The UI Power Plant's partnership with the Quaker Oats Company helps to keep Quaker's 1200-employee production operation in Cedar Rapids competitive, while also providing a use for a renewable energy source product. Additionally, The State of Iowa recognized the UI with two 2003 Iowa Environmental Excellence Awards: "Special Recognition in Air Quality" and "Special Recognition in Energy Efficiency/Renewable Energy." This biomass fuel project provides learning opportunities for the UI's students and faculty.

### **Innovation and creativity**

The team responsible for testing oat hull combustion in the CFB found there was virtually no oat hull burning information available in the public domain. Most of the technical experience was in Europe, where bioenergy has been utilized for decades; however, specific information related to burning oat hulls in a CFB furnace was not readily accessible.

After coordinating with the Iowa Department of Natural Resources for a biomass test burn, the experiment proceeded with an initial test of Resifil. Mixed results led the team to try burning unprocessed oat hulls. Oat hulls, about the size of sunflower seeds, are very light-weight. Quaker Oats had to figure out how to load and transport the oat hulls. The Power Plant had to design, procure, and install a pneumatic injection system. Part of this system included a separate, more compatible fuel silo, and designing, procuring and installing pneumatic blowers, fuel injection nozzles, transport piping and fittings, safety interlocks, and new boiler control logic specifically designed for the biomass fuel. These modifications needed to be done in a manner that would not have a negative impact on the existing coal systems. The test with unprocessed oat hulls proved a resounding success for the UI Power Plant, and for Quaker Oats.

### **Portability and sustainability**

Learning from the success of this project, the UI Power Plant team recognized several key factors necessary for a successful biomass fuel project:

- Proximity to the source of biomass supply;
- Reasonable transportation costs from the supply;
- An adequate supply of biomass;
- A mutual desire between the supplier and the UI to make this successful;
- A circulating fluidized bed boiler.

### **Management commitment and employee involvement**

From inception through testing and into full production, a team of Power Plant employees worked on the biomass fuel project. People selected for the team were motivated, creative, long-term employees of the plant. Each of them could be described as a “self starter.” There was not a formal team charter, just a strong desire to prove the concept and drive to success. Their mission was clear: “Make biomass burning at the Power Plant a reality.”

The UI administration played an essential role in the project’s success by being willing to try an innovative practice, willing to accept the time necessary for permitting and testing, and accepting of the initial costs for investments in materials handling systems and boiler modifications that, if successful, would be recouped in later savings.

## Documentation

Table 1 summarizes results of the emissions testing. These results are discussed in more detail in the next section (Biomass Stack Emissions Testing).

	SO <sub>2</sub> (lb/mmBtu)	NO <sub>x</sub> (lb/mmBtu)	PM (lb/hr)	CO (lb/mmBtu)	VOC (lb/mmBtu)
Permit Limit	1.0	0.40	6.69	0.30	N/A
National Average	0.83	0.40	N/A	N/A	N/A
100% Coal	0.21	0.22	2.51	0.60	0.33
50% Oat Hulls	0.13	0.18	1.57	0.03	0.11
80% Oat Hulls	0.08	0.18	1.32	0.20	0.18
% Decrease	62%	18%	47%	67%	46%

Table 1

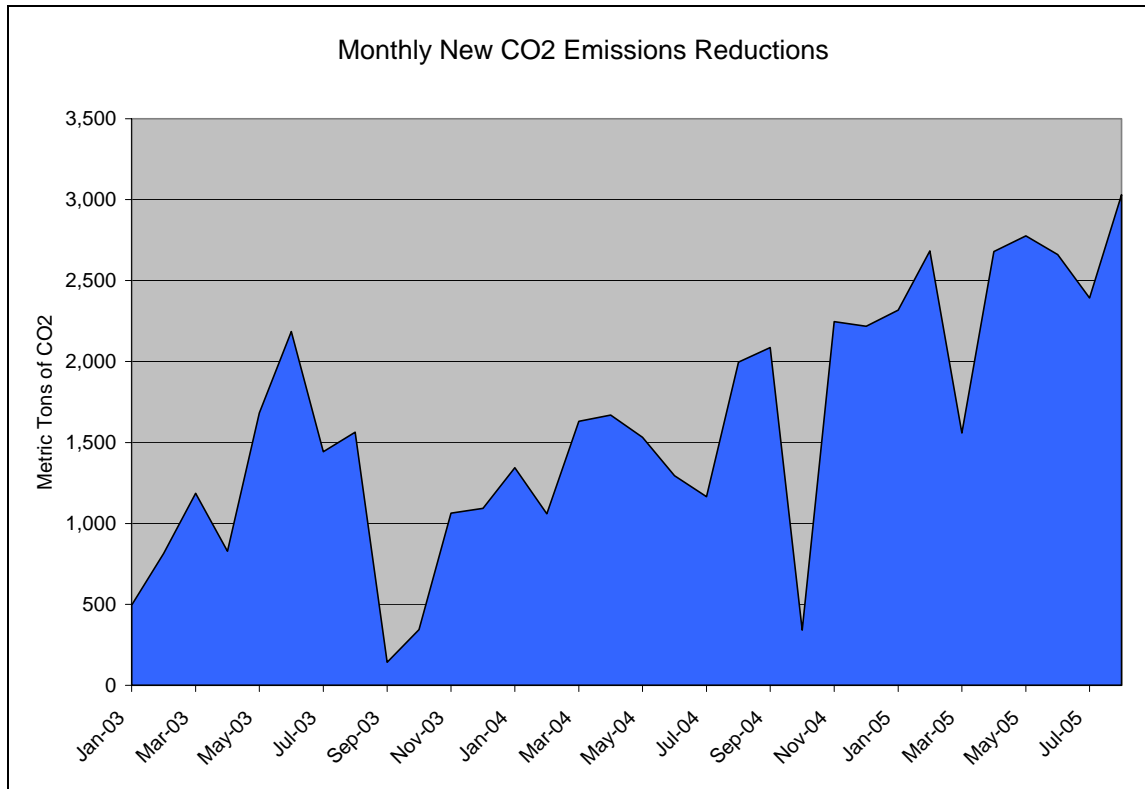
During the eight-month test period in 2003, 16,077 tons of oat hulls were consumed, displacing 8,065 tons of coal. The expected oat hull consumption rate for Boiler #11 is around 35,000 tons per year, displacing 23,000 tons of coal. In addition to substantial reductions of regulated air pollutants, green house gas emissions are expected to be reduced by 55,000 short tons of new CO<sub>2</sub> per year. The oat hulls represent over 30% of the solid fuel energy input to Boiler #11, and about 14% of the total fuel purchased for the UI.

## Conclusion

The UI Power Plant has embraced the economic and environmental advantages of burning biomass fuel. From a business perspective, this project was and is an economic “win-win-win” situation. It helps the UI, Quaker Oats, and the State of Iowa. Combining creative engineering and operating floor know-how, a team of experienced power plant staff partnered with an industry leader to pioneer a cutting edge, sustainable technology. Providing an economic and reliable outlet for oat hulls helps to ensure the Quaker Oats Cedar Rapids Facility remains competitive and viable. The UI purchases oat hulls at a cost significantly below an equivalent amount energy from coal. This represents a significant reduction in purchased energy cost for the UI. Finally, reducing green house gas emissions and regulated pollutants, as a result of burning biomass, produces an environmental benefit that is greatly appreciated and lauded by the UI community.

## Carbon Dioxide Reductions and Coal Displacement

During the period January 2003 through August 2006, 74,527 short-tons of biomass have been consumed at the UI main power plant. This fuel has replaced 46,051 short-tons of coal. The CO<sub>2</sub> that was emitted when the oat hulls burned did not contribute to increasing the global inventory of CO<sub>2</sub>. Using an emission factor of 2,236.8 kg of CO<sub>2</sub> for each short ton of coal, monthly CO<sub>2</sub> reductions are calculated and shown in figure 1.



**Figure 1**

The monthly amount of biomass being burned has increased steadily since the program began. The short periods with minimal reductions are associated with planned CFB boiler outages. During these periods, no biomass could be burned. 2003 was the project testing and permitting period. In 2004, the UI began a four-year contract with Quaker for supply of oat hulls. As the plant operators have become proficient at co-firing oat hulls, the maximum burn rate has been sustained for longer and longer periods of time. Additionally, the oat hull transportation system efficiency increased, and Quaker was operating at higher production capacities. It is likely the maximum burn rate will not increase significantly beyond the maximum reached in August 2005. The unit was running at full-load all month and biomass deliveries were scheduled 24/7, even during weekend periods.

### **Oat Hull Fuel Description**

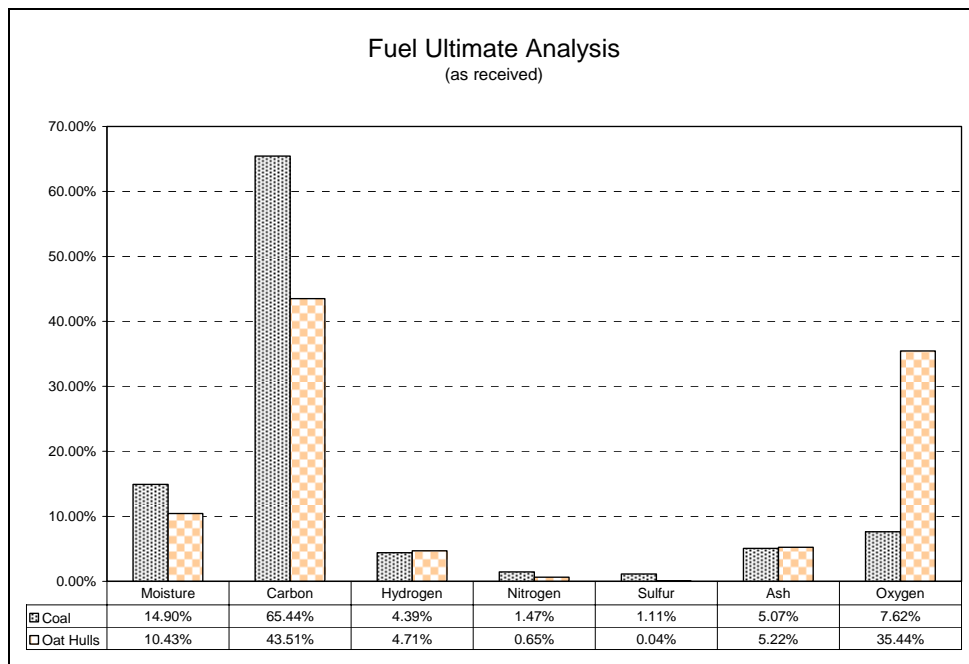
Oat hulls are produced as a residual from the oat milling process. The raw oat grain is milled and the protein containing center removed. The surrounding material has little protein but, does have a heat content of about 7,000 Btu/lb. This compares to coal that is used in the CFB boiler with a heat content of about 11,000 Btu/lb.

Figure 2 compares the chemical composition of oat hulls and the type coal fired in the CFB boiler. Significant differences include the percentages of carbon, oxygen, and sulfur.

The lower carbon content in the oat hulls accounts for the lower heat content, when compared to coal. However, this carbon became part of the fuel through photosynthesis, where CO<sub>2</sub> was removed from the atmosphere and oxygen released back into the atmosphere. The carbon in coal comes from fossil fuel located underground. When carbon in coal (or any other underground fuel source) is burned, the CO<sub>2</sub> released to the atmosphere increases the global inventory of this green house gas. However, the CO<sub>2</sub> that results from burning biomass does not increase the global inventory, because it was already in the atmosphere before the plant grew.

Oat hulls also have a much higher percentage of oxygen (35% versus 7.4%), compared to coal. This higher oxygen content requires the boiler combustion control system be modified to reduce the amount of combustion air supplied to the furnace, as the firing rate of oat hulls is increased.

Finally, the amount of sulfur in oat hulls is almost zero, compared to coal. Emissions controls are required to reduce the potential SO<sub>2</sub> emissions by a minimum of 90%. This reduction is accomplished by injecting powdered limestone into the furnace. The calcium in the limestone reacts with the SO<sub>2</sub> produced when the sulfur in the coal burns. This reaction produces calcium sulfate, a solid, which is removed with the boiler ash.



**Figure 2**

## Emissions Stack Testing Results

The figures 3 through 7 summarize stack emissions testing results conducted by Mostardi-Platt Environmental in August 2003. This testing was required as part of the air quality permitting process.

Three runs were performed with the boiler at maximum load. First, the unit was fired with 100% coal fuel. The second run was performed with 50% heat input from each biomass and coal. The final run was conducted at a biomass heat input rate of 80%.

Figure 3 illustrates the reduction in SO<sub>2</sub> emissions with increasing biomass firing. This result was expected because the oat hulls have virtually no sulfur content. The CFB boiler removes a minimum of 90% of the potential SO<sub>2</sub> emissions by injecting powdered limestone into the combustion process. The calcium in the limestone combines chemically with the sulfur dioxide to produce calcium sulfate, a solid. In this manner the SO<sub>2</sub> emissions are removed as a solid material with other boiler ash, versus being emitted to the atmosphere as sulfur dioxide.

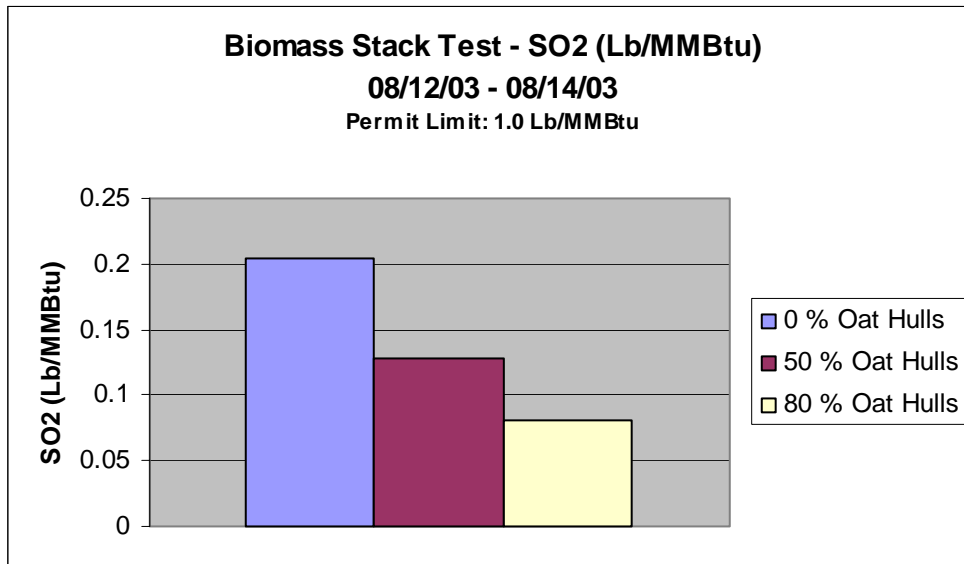


Figure 3

Figure 4 shows a decrease in NO<sub>x</sub> emissions when co-firing oat hulls. However, the NO<sub>x</sub> emissions level did not continue to significantly decrease as oat hull heat input was increased from 50% to 80%. A characteristic of CFB boilers is that NO<sub>x</sub> emissions will increase with increasing limestone consumption. Limestone consumption is also a function of the sulfur content of the fuel. Sufficient limestone must be added to ensure a minimum of 90% SO<sub>2</sub> removal. As oat hulls are added to the fuel the amount of limestone required to achieve a 90% SO<sub>2</sub> removal rate decreases. This decrease in limestone consumption with oat hull co-firing may account for the accompanying drop in NO<sub>x</sub> emissions.

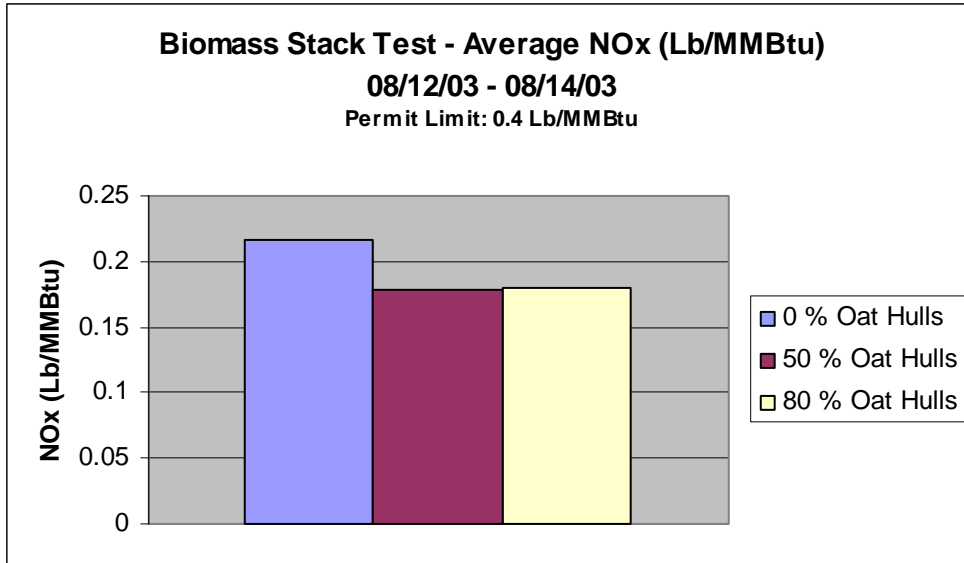


Figure 4

Figure 5 illustrates that particulate emissions decrease with increasing biomass co-firing rates. This result was not anticipated. In fact, there was concern that particulate emissions would increase, with increasing biomass firing rates. Additional study is needed to determine the cause of decreasing particulate emissions with increasing biomass firing rates.

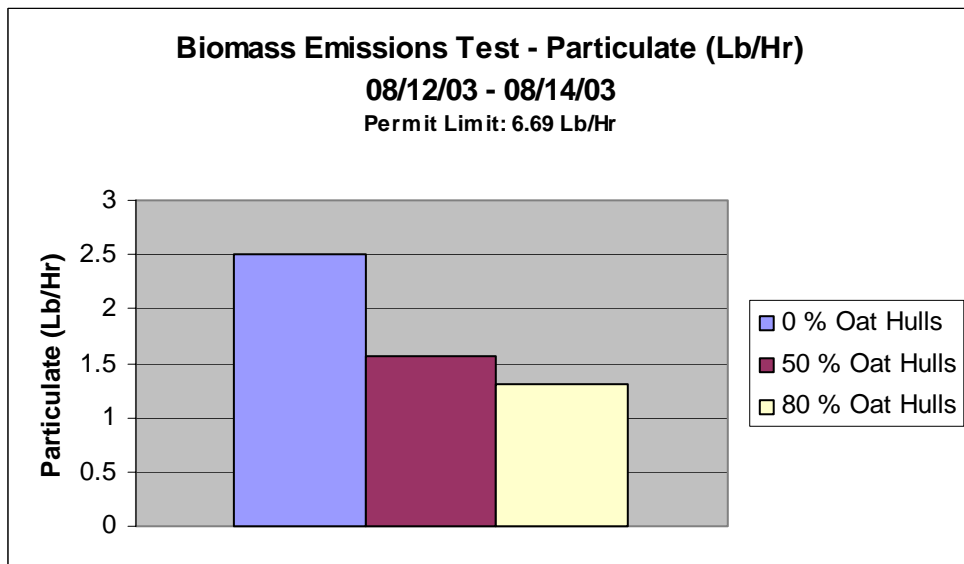


Figure 5

Figure 6 illustrates carbon monoxide emission rates also decrease as oat hull firing is increased. The level of carbon monoxide emissions is indicative of how complete the combustion process is. As carbon monoxide emissions decrease, more complete combustion is occurring. One possible explanation for the trend of decreasing carbon monoxide emissions with increasing oat hull firing rates is that the oat hulls are contributing to more complete combustion in the boiler.



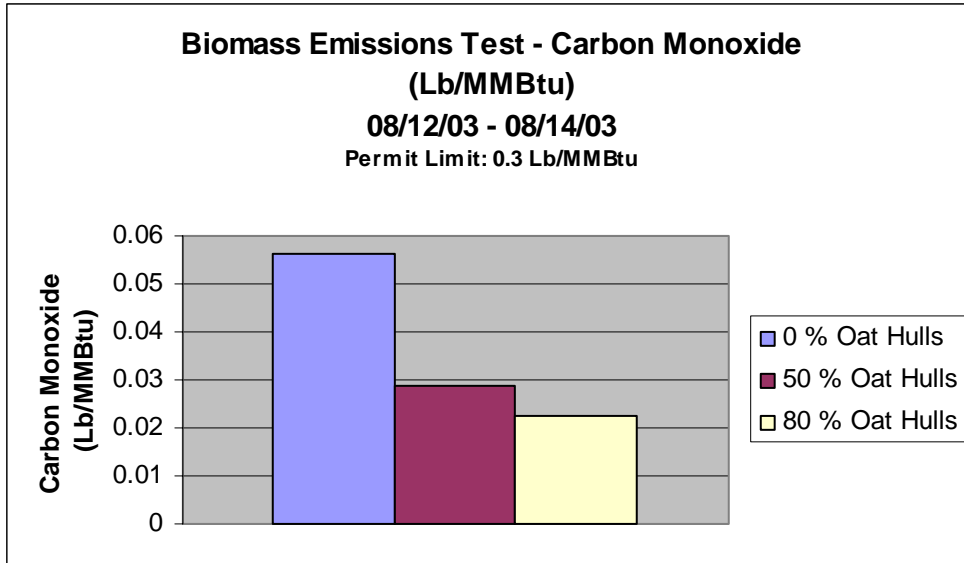


Figure 6

Figure 7 illustrates total hydrocarbon emissions are lower with biomass co-firing, compared to all coal. However, the reason for this, or the increase in hydrocarbon emissions at higher biomass firing rates is not apparent at this time. More study is needed to understand this phenomenon.

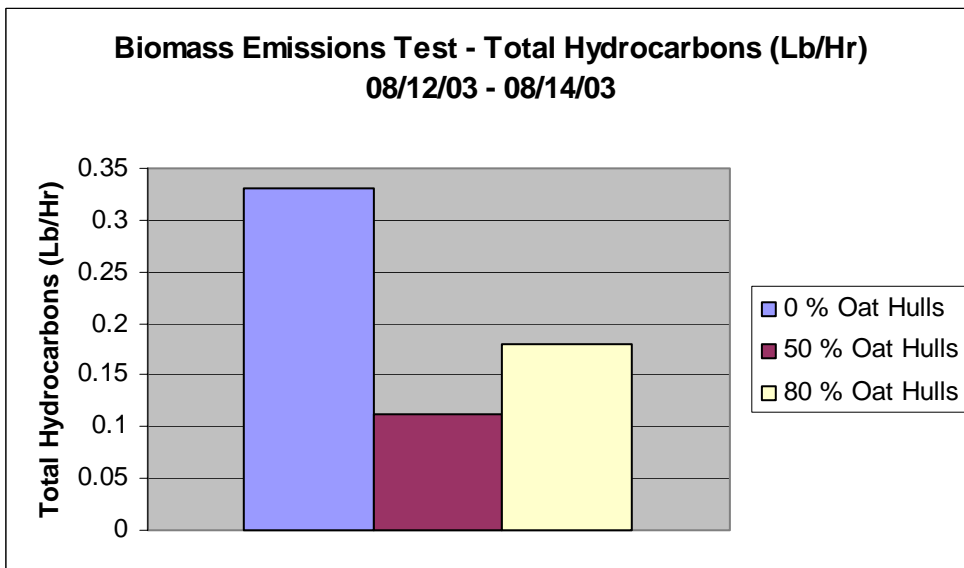
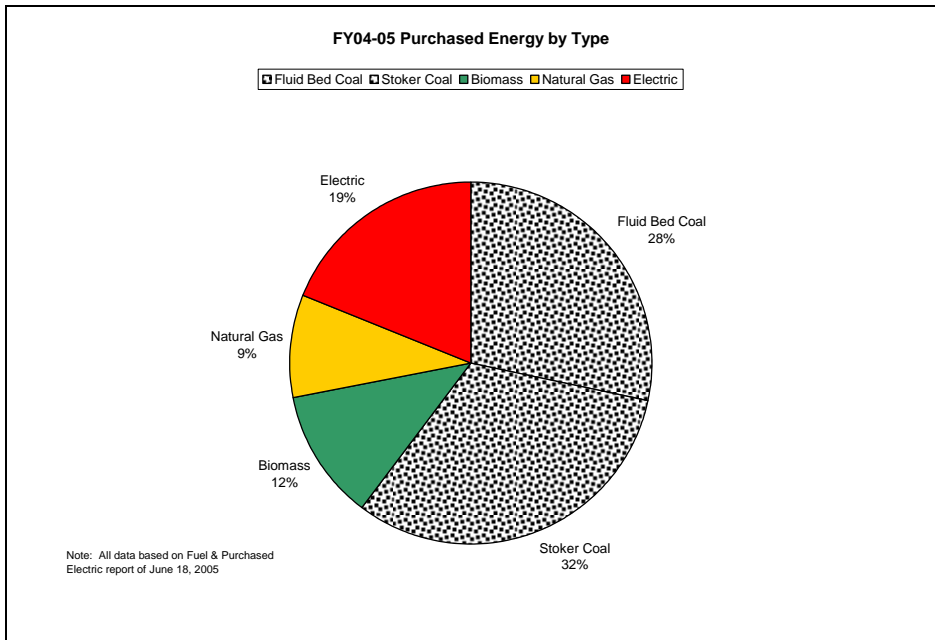


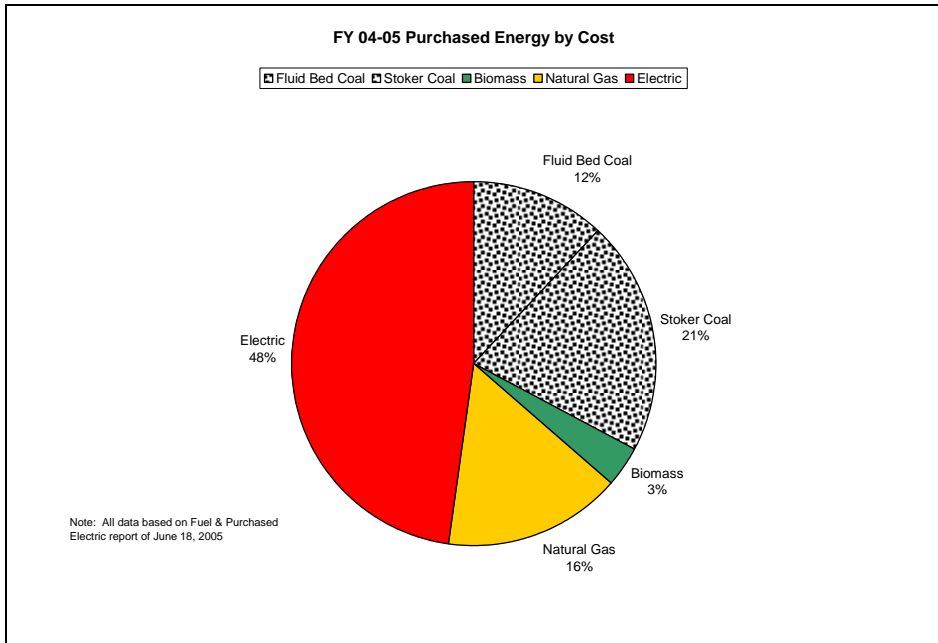
Figure 7

### Purchased Energy Discussion

The UI purchases four forms of energy. They are coal (currently two contracts), electric power, natural gas, and biomass. It is useful to compare the relative amounts of purchased energy, both from a units consumed and a price for each type. Figure 8 shows the relative amounts of the four forms of purchased energy and figure 9 shows the relative expense for each form of energy.



**Figure 8**



**Figure 9**

The UI operates a combined heat and power plant with two solid fuel boilers and three gas boilers. Controlled extraction steam turbines provide the ability to economically and efficiently cogenerate about one-third of the total facility electric power needs.

It is significant that 48% of the purchased energy expense is used for only 19% of the purchased energy (electric). Whereas, biomass (oat hulls) represents only 3% of the purchased energy cost and provides 12 % of the facilities total purchased energy requirements. All the biomass that is burned displaces coal in the CFB boiler. The cost of biomass is about one-half that of coal.

## Circulating Fluidized Bed Boiler Discussion

Figure 10 is a reproduction of one of the computer screens used to monitor and operate the CFB. In this process air is injected into the furnace with primary air (PA) and secondary air (SA) fans. The air flows from the fans and through an air heater where heat in the exhaust gas is recycled into the combustion process. The air then flows into the bottom of the combustion furnace and up through a grid floor. The grid floor “fluidizes” the material in the furnace. The material in the furnace resembles beach sand with chocolate chips when it is cool. About 25 to 40-tons of material is in constant circulation in the boiler furnace while the unit is operating. The sand like material is limestone, both that which has reacted with the SO<sub>2</sub> and that which has not reacted, as well as light boiler ash. The chocolate chip like material is the unburned coal. During furnace operation, this material would be burning.

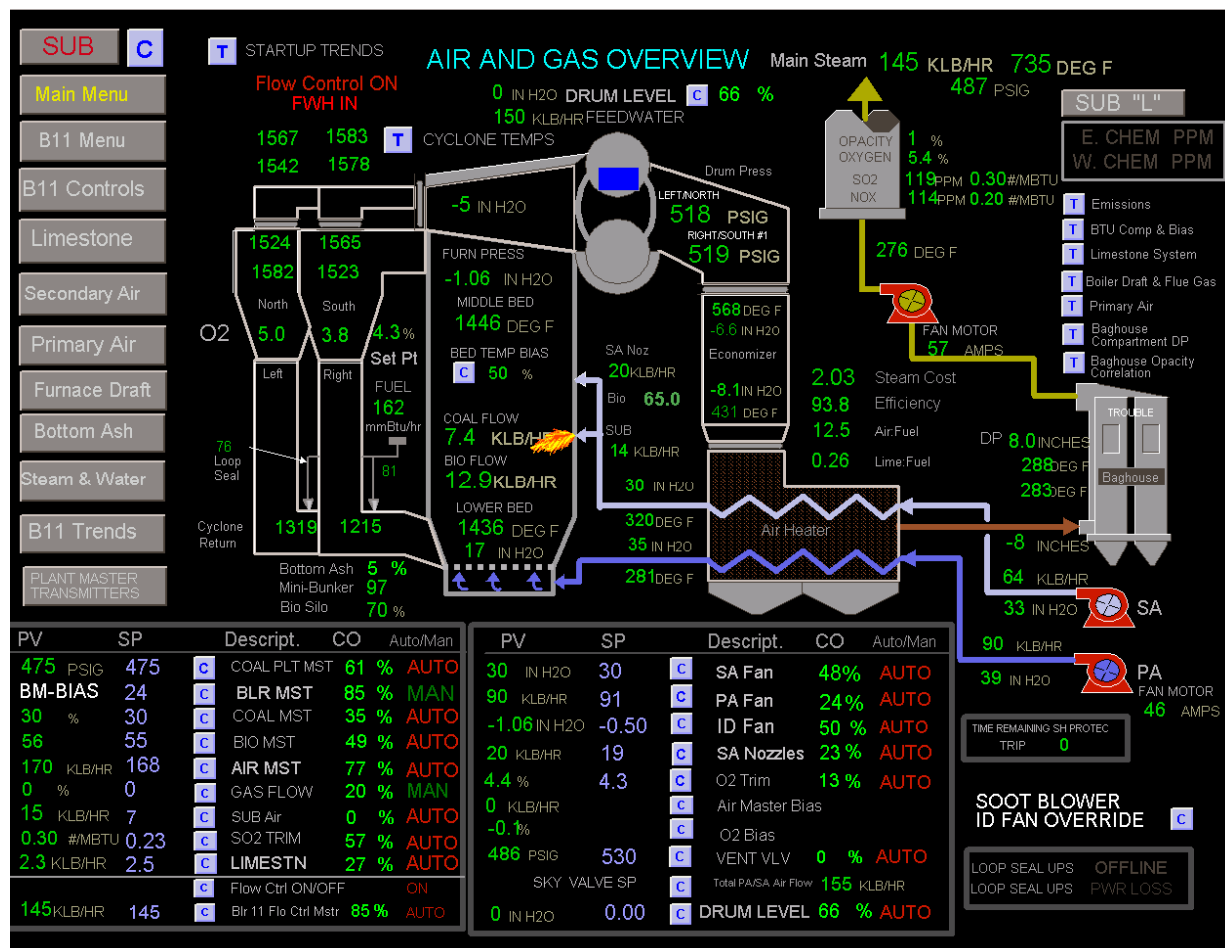


Figure 10

The furnace material becomes less dense as it rises in the furnace. When it reaches the top of the furnace it is directed into cyclones. The North and South cyclones spin the combustion gases and bed material. This action causes the gases and light ash to separate from the heavy material. Heavy material is returned to the bottom of the furnace and coal is added before it is reinjected into the furnace. The light ash and boiler gases continue through the boiler heat recovery equipment, flue gas baghouse filter, and finally are forced up the boiler stack by the induced draft (ID) fan.

Opacity, oxygen, SO<sub>2</sub>, and NO<sub>x</sub> emission levels are continuously measured by probes that are located in the boiler stack. This information is permanently archived and reported to regulatory agencies on a periodic basis.

Steam is generated in the boiler by metal tubes containing water on the inside and exposed to the hot combustion temperatures on the outside of the tube. They serve as a boundary to contain the fuel combustion. As the water boils, the steam is collected in a steam drum. It is then passed through a set of tubes called a super heater. This process adds additional heat to the steam before it leaves the boiler and is used to produce electric power and thermal energy for the campus.

A CFB is capable of burning a wide variety of fuels. The UI CFB was originally designed to burn 100% coal. The unit has been adapted to burn biomass (oat hulls) using a special fuel injection system (figure 11). The biomass is co-fired with coal. It has been successfully tested at furnace heat input rates of 80% biomass and 20% coal. Normal operating conditions are 50% heat input from biomass and 50% heat input from coal.

The biomass fuel system consists of a semi-truck unloading station, pneumatic pull transport system from the unloading station to the storage silo, fuel feed twin-screw feeder, weigh belt, rotary air locks, blowers, lean phase transport piping and fittings, and boiler fuel injection nozzles.

The unloading system has the ability to unload one 53-ft walking floor trailer in 45-minutes. The average load is about 22-tons of oat hulls. The material is discharged out the back of the trailer by the walking floor. Oat hulls fall into a screw feeder at the bottom of the unloading hopper. The screw feeder moves the hulls to the transport system suction line at one end of the hopper. The hulls are vacuum dragged up to a cyclone located on the top floor of the boiler house. The cyclone separates the hulls from the transport air. The hulls are discharged from the bottom of the cyclone, through a chain conveyor, and into the top of the biomass silo. The transport air is pulled through the cyclone by the pneumatic unloading system blower.

Oat hulls flow by gravity out of the biomass silo through a twin screw feeder and onto a weigh belt feeder. Both the twin screw feeder and the weigh belt are variable speed and the speed is controlled by the biomass burn rate. Oat hulls discharge off the end of the weigh belt and into two air locks. The air locks provide a pressure seal between the weigh belt (at atmospheric pressure) and the lean phase transport system piping. Master Fuel Trip slide gate isolation valves are located between the weigh belt and air lock. In the event of a boiler trip, these valves operate to isolate the biomass fuel system from the boiler furnace.

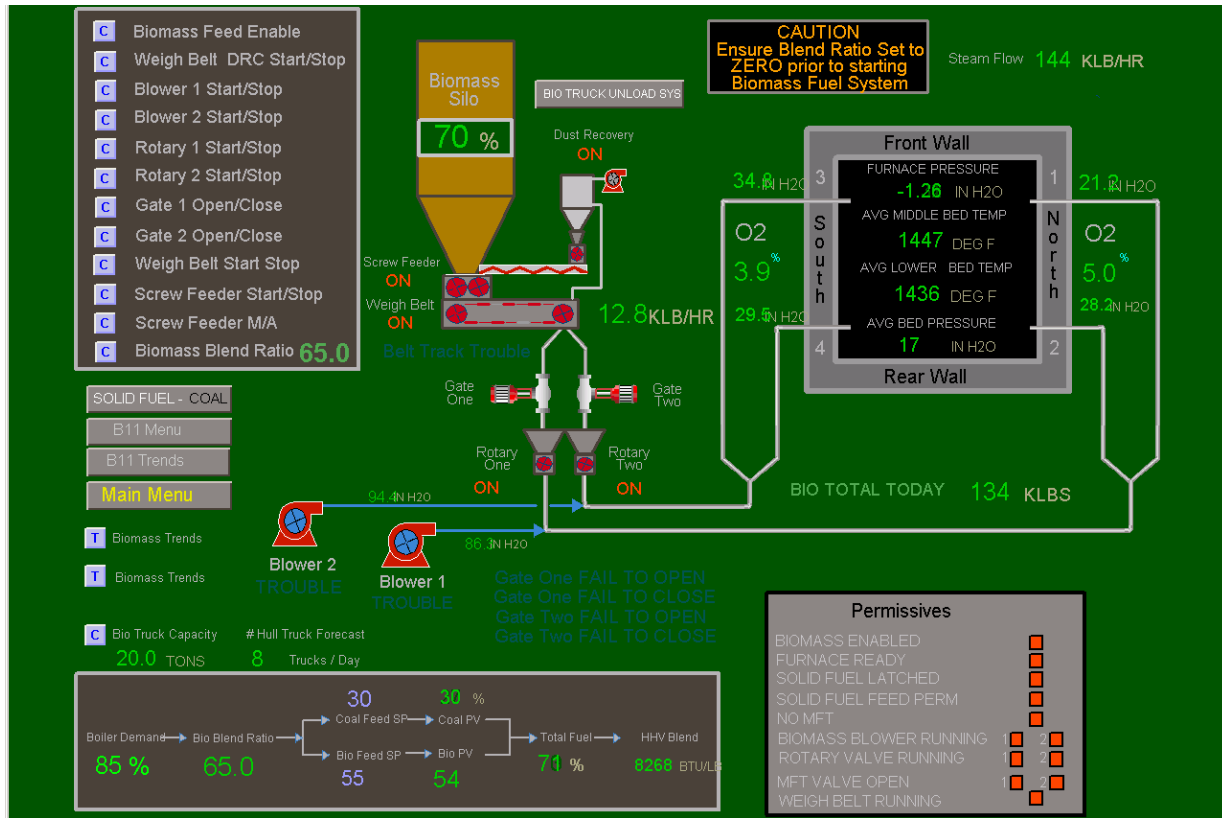


Figure 11

Once the oat hulls are in the pneumatic fuel feed system piping, they move through piping, splitter, and fittings to the boiler fuel injection nozzles. There are four nozzles, two on each boiler side wall. They blow the biomass into the furnace through existing secondary air ports.

The biomass combusts in the furnace much like a gas flame. There is an intense fireball in front of each nozzle where the hulls burn in a very short time. The ash resulting from the hull combustion is conveyed up to the top of the furnace where it is removed with the rest of the boiler fly ash in a fabric filter bag house.

## Awards

### **Iowa Governor's Environmental Excellence Awards**

#### **Air Quality**

#### **Energy Efficiency/Renewable Energy**

The **University of Iowa Main Power Plant** provides heating, cooling and electricity to the 1,900-acre university campus. In a partnership with Quaker Oats in Cedar Rapids, the power plant has begun using oat hulls as a renewable energy source. The oat hulls are fed into a furnace using an innovative injection system, displacing more than 8,000 tons of coal in an eight month period. The project has resulted in a substantial reduction of regulated air pollutants, as well as green house (carbon dioxide from fossil fuels) reductions of 19,400 tons, a 62 percent decrease in sulfur dioxide, a 67 percent decrease in carbon monoxide and a 47 percent decrease in particulate matter. The plant plans to continue using oat hulls as an energy source.

<http://www.iowadnr.com/other/ee/03winners.html>



Back Row (left to right): Joe Schwarzhoff (Power Plant Engineer), Eric Lee (Quaker Oats engineer), Ferman Milster (Associate Utility Director), Iowa Governor Tom Vilsack, Steve Jenkins (Quaker Oats),

Front Row (left to right): Don Bream (Power Plant Electronics Technician), Bob Harding (Power Plant engineer), Marc Mohn (Power Plant Electronics Technician).

## The APPA Effective and Innovative Practices Award



Recognition

### EFFECTIVE & INNOVATIVE PRACTICES AWARD WINNERS

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⌘ **University of Iowa**  
*Biomass Fuel Project*

⌘ **University of Miami**  
*How the University of Miami's Facilities Administration Department Uses  
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⌘ **University of Victoria**  
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<http://www.appa.org/recognition/innovativewinners.cfm?printval=yes> 9/19/2005

## **Chicago Climate Exchange**

CCX is the world's first and North America's only voluntary, legally binding rules-based greenhouse gas emissions allowance trading system. CCX members reflect a cross-section of major public and private sector North American entities, including Ford Motor, International Paper, IBM, American Electric Power, Manitoba Hydro, Amtrak, the City of Chicago and Oklahoma University, as well as non-industrial environmental innovators such as World Resources Institute, Pax World and the Rocky Mountain Institute, and cities such as Chicago, Oakland, Boulder and Portland. Reductions achieved through the CCX pilot market are significant in scale and impact. CCX Members gain practical experience by building an efficient emissions management and monitoring system, while also acquiring cutting edge measurement and trading skills that will be needed in short and long term as the world comes to terms with the climate change challenge. The Chairman and CEO of CCX is economist and financial innovator Dr. Richard L. Sandor, who was named a Hero of the Planet by Time magazine for his work in founding CCX.

The University of Iowa has been a Member of the Chicago Climate Exchange since 2004. Through its membership in CCX, Iowa has made a commitment to reduce its own emissions of greenhouse gases by 4 percent below the average of its 1998-2001 baseline by 2006. The University was the first Iowa-based commercial entity to do a transaction in the Chicago Climate Exchange by purchasing 2,000 tons of carbon credits to meet its reduction commitment from Iowa farmers through the Iowa Farm Bureau program. The University Power Plant is embarking on an innovative biomass project, burning oat hulls from Quaker Oats in Cedar Rapids. The plant burned 27,000 tons of oat hulls last year. Each ton burned displaces more than a half-ton of coal. Burning that amount of coal puts 2.5 tons of carbon dioxide into the atmosphere.