Brief statement of program/practice and its 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 University of Iowa, 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, was applauded by sustainability advocates, and was recognized as a dramatic example of how higher education facilities management can play a key role in enhancing efforts to generate economic development.
Institutional benefits

The Biomass Fuel Project has been an exciting opportunity for The University of Iowa 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 University of Iowa Power Plant supplies 100% of the campus heating and 30% of the campus electrical demand. In 2001, prior to burning a mixture of coal and biomass, the UI Power Plant was purchasing 110,000 tons of coal, annually. Two coal burning boilers produce the majority of energy: Boiler #10 and Boiler #11. Boiler #11, a circulating fluidized bed (CFB) unit, was installed with the best available control technology for sulfur dioxide (limestone injection and a particulate collecting bag house). Until the biomass fuel project, Boiler #11 was consuming 60,000 tons of coal annually. With Boiler #11 using oat hulls in place of 25,000-35,000 tons of coal, the institution is realizing an annual cost saving of a half-million dollars.

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. The addition of oat hulls to the fuel mix significantly reduced the amount of regulated air pollutants (SO2, NOx, PM, CO and VOC) emitted by Boiler #11, even though the pollution control features were already environmentally advanced. The results were surprising: Besides substantial reductions of regulated air pollutants, green house gas emissions (carbon dioxide from fossil fuels) are also reduced when burning biomass. The UI is on track to reduce greenhouse gas emissions by at least four percent by the year 2006, from a baseline established in 1998-2001.

In 2004, the projected reduction in green house gas emissions enabled The University of Iowa to join the Chicago Climate Exchange, a green house gas trading pilot program for emission sources and offset projects. The projected excess reduction of carbon dioxide emissions will translate into carbon dioxide emissions credits, which will be traded to other exchange members in need of emission reduction credits. Selling excess credits could be worth thousands of dollars to The University of Iowa.

Additionally, The State of Iowa recognized the University with two 2003 Iowa Environmental Excellence Awards: “Special Recognition in Air Quality” and “Special Recognition in Energy Efficiency/Renewable Energy.”

The University has been able to accommodate changes to its fuel mix without increasing the size of its workforce, largely due to automation and an advanced control system that allow staff to operate and monitor boilers, turbines, and other plant equipment via computer.

Now the University is looking at Boiler #10. It is a stoker boiler, with a fundamentally different combustion process. However, the UI Power Plant believes it is feasible to burn oat hulls in Boiler #10 and will partner with the College of Engineering to study the stoker boiler combustion process using computational fluid dynamics computer modeling.

This biomass fuel project serves as a model for the University’s students and faculty, and provides learning opportunities for future environmentalists and industrialists. Already, the program is the basis for case study by the International District Energy Association, and is listed in reference materials for grades 7-12 by ENC: Curriculum Resources. The favorable publicity continues to shed light on innovation at the University of Iowa.

Additionally, 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.
Innovation and creativity

When Quaker Oats learned that the University of Iowa Power Plant was interested in bioenergy, both parties began searching for information about the special needs of biomass combustion. Most of the technical experience was in Europe, where bioenergy has been utilized for decades. Specific information related to burning oat hulls in a CFB furnace was not readily accessible. Some of the initial concerns about using oat hulls as a source of fuel in the circulating fluidized bed boiler included:

- An incomplete burn could leave large amounts of carbon in the ash or accumulating in specific areas of the boiler with adverse efficiency and reliability impacts.
- Increased emissions, especially of volatile organic compounds (VOCs) and particulate matter (PM), might exceed permit levels, or perhaps overload the bag house flue gas clean up equipment.
- Biomass material handling (especially Resifil in the presence of moisture) would increase fuel handling system and equipment corrosion and wear, leading to premature failure of systems.

The initial biomass test involved blending Resifil (an organic powder that remains after cooking oat hulls with sulfuric acid and distilling the vapors into furfural, an organic solvent) and coal together, before going into the boiler. This was the lowest cost and easiest method to accommodate biomass burning with the existing fuel handling systems. It was decided to limit the biomass burn rate to 50% by weight (6 tons per hour when fired with coal).

After coordinating with the Iowa Department of Natural Resources for a biomass test burn, the experiment proceeded with an initial test of Resifil. The first test at the UI Power Plant yielded mixed results. The major obstacle was premature burning of Resifil after it was introduced into the boiler. While the coal and Resifil were being fed into the furnace, the Resifil would ignite before the coal, making accurate control of combustion temperatures impossible; at times temperatures would increase beyond design limits of the boiler. In order to control the process, it was necessary to reduce the maximum quantity of Resifil that could be blended with coal. Realizing that a fuel blending approach would not yield long-term satisfactory results, UI concluded it would be necessary to transition to a pneumatic injection system for feeding the biomass fuel into the boiler, before proceeding with additional biomass test burn experiments.

Quaker Oats had been producing furfural and Resifil from oat hulls for 80 years. Their traditional method to dispose of Resifil was changing and the furfural chemical market was collapsing. These conditions led Quaker to make the business decision to abandon furfural and Resifil production, and seek alternate methods for disposing of oat hulls left over from producing food products.

The focus of the biomass test burning experiment then shifted to burning unprocessed oat hulls using a pneumatic injection system. Oat hulls, about the size of sunflower seeds, are very light-weight, 9 to 11-lbs per cubic foot versus coal at 55-lbs per cubic foot; Resifil is at 13-lbs per cubic foot. 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 in order to avoid having the hulls "bridge", a condition that was observed when oat hulls were placed in the existing coal silos and would not flow out into the fuel handling system. It was also necessary to design, procure, and install 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.

After installation of a pneumatic fuel injection system, oat hull testing resumed. Smoke stack testing was performed at various blend ratios of biomass and coal to quantify the changes in pollutant emission levels. This testing demonstrated and validated additional positive environmental impacts of oat hull combustion due to decreasing criteria pollutant emissions. The test with unprocessed oat hulls proved a resounding success for the University of Iowa Power Plant, and for Quaker Oats. All of the concerns about fouling, corrosion, and temperature control were proven void and regulated pollutant emissions decreased when oat hulls were burned.
Portability and sustainability

The University of Iowa 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 University, Quaker Oats, and the State of Iowa. The Quaker Oats Cedar Rapids Facility has about 1,200 employees. Providing an economic and reliable outlet for oat hulls helps to ensure this facility remains competitive and viable. The UI purchases oat hulls at a cost of about half that for an equivalent amount energy from coal. This represents a significant reduction in purchased energy cost for the University of Iowa. Finally, reducing greenhouse 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.

The burning of biomass fuel is recognized as a source of green energy because there is no net increase of CO2 into the atmosphere. Instead, it is viewed as a closed environmental system where the oat plant takes CO2 out of the atmosphere during the growing cycle and releases it during the burning cycle. The burning of coal and natural gas, on the other hand, contribute to a net gain in atmospheric CO2 concentrations.

The UI Power Plant continues to build toward the future with bioenergy, and is drafting plans for larger biomass storage silos, and a new boiler capable of producing "green energy" through biomass combustion. UI has determined that additional biomass fuel is available in the local area, from Quaker and other industrial sources. Currently, much of this material is going to land fills, or other uses that are not as beneficial as using the material as a fuel source. The UI biomass project will serve as an example for further development of biomass combustion at the UI, or other biomass fuel project developers in the local area.

The success of the UI biomass fuel project has achieved an advantageous balance between economics and the environment. Additionally, the greening of the UI Power Plant has enabled the campus to be among the first public universities to join the Chicago Climate Exchange (CCX). This has encouraged campus support and good will, a support base for a new solid fuel biomass burning furnace, and the opportunity to work with students and faculty.

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 University to make this successful;
- A circulating fluidized bed boiler.

In addition, it is necessary to recognize the role that University administration must play. The leadership must be 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, will be recouped in later savings.
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. Included on the power plant team were:

- Three power plant engineers, one with a team leader role, one with a contractor coordination role, and the third with environmental testing and permitting responsibilities.
- Electronics and instrumentation technicians
- Mechanical maintenance staff
- Chief Operator (shift supervisor) from the plant operations staff.

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.”

They were people that are very knowledgeable in their field, but willing to solicit input and help from various sources when they encountered an area they needed additional information. The Power Plant team was supplemented with other resources from Quaker Oats, the boiler manufacturer, and consulting engineers as necessary.

The stick-to-it attitude of the team members was an essential element of the team’s success. Due to the experimental nature of this effort, most attempts did not work as desired or required the first time.

The team was responsible to develop methods and procedures to transport, unload, and convey the material from Quaker Oats to the power plant boiler. They developed budget estimates for the various stages of the testing program and the final production system.

Management at the Power Plant kept providing encouragement and resources to continue the project. There was high level support by the University administration and faculty for the project to succeed. The administrative support overcame barriers to innovation that would have resulted in numerous delays.
Documentation, analysis, customer input, and benchmarking

**TEST #1:** The first round of tests used Resifil. Some of the initial concerns proved unwarranted: no fouling or corrosion was seen in the furnace or on the heat exchange surfaces; the Resifil burned completely with no heavy emissions and actually reduced ash generated. Sulfur dioxide \((\text{SO}_2)\) did not appreciably decrease, mainly due to the fact that sulfuric acid is added to the oat hulls as a part of the process that produces Resifil. When the acidic Resifil mixed with the moisture present on the coal, the fuel handling conveyors corroded badly, leading to failures and lost time. Another major obstacle during this test was the premature burning of the Resifil, with an accompanying excursion of furnace temperatures. The premature combustion limited the quantity of Resifil able to be fed into the boiler to 3.6 tons per hour and increased \(\text{NO}_x\), and carbon monoxide \((\text{CO})\) emissions as well.

<table>
<thead>
<tr>
<th></th>
<th>(\text{SO}_2) (lb/mmBtu)</th>
<th>(\text{NO}_x) (lb/mmBtu)</th>
<th>Particulate Matter (PM) (lb/hr)*</th>
<th>(\text{CO}) (lb/hr)</th>
<th>Volatile Organic Compounds (OC) (lb/hr)</th>
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</thead>
<tbody>
<tr>
<td>Permit limit</td>
<td>1.0</td>
<td>0.40</td>
<td>6.69</td>
<td>0.30</td>
<td>N/A</td>
</tr>
<tr>
<td>National average</td>
<td>0.83</td>
<td>0.40</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>100% Coal</td>
<td>0.21</td>
<td>0.22</td>
<td>8.97*</td>
<td>0.08</td>
<td>0.71</td>
</tr>
<tr>
<td>20% Resifil</td>
<td>0.22</td>
<td>0.21</td>
<td>7.21*</td>
<td>0.08</td>
<td>0.53</td>
</tr>
<tr>
<td>50% Resifil</td>
<td>0.23</td>
<td>0.28</td>
<td>6.96*</td>
<td>0.07</td>
<td>0.41</td>
</tr>
<tr>
<td>% Change</td>
<td>10% increase</td>
<td>27% increase</td>
<td>22% decrease</td>
<td>13% decrease</td>
<td>42% decrease</td>
</tr>
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</table>

* Later determined the particulate matter test method was flawed and results were questionable.

**TEST #2:** After the mixed success of the first test with Resifil, testing proceeded with oat hulls. Because the preliminary emission performance results were so promising, it was decided to raise the combustion rates to 80% by Btu basis, or 10.5 tons per hour of biomass fuel. This biomass burn rate greatly exceeded initial projections. Extended testing confirmed there were no long term fouling & corrosion concerns within the furnace.

<table>
<thead>
<tr>
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<th>(\text{SO}_2) (lb/mmBtu)</th>
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</tr>
</thead>
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<tr>
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<tr>
<td>National average</td>
<td>0.83</td>
<td>0.40</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>100% Coal</td>
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<td>0.22</td>
<td>2.51</td>
<td>0.06</td>
<td>0.33</td>
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<tr>
<td>50% oat hulls</td>
<td>0.13</td>
<td>0.18</td>
<td>1.57</td>
<td>0.03</td>
<td>0.11</td>
</tr>
<tr>
<td>80% oat hulls</td>
<td>.08</td>
<td>0.18</td>
<td>1.32</td>
<td>0.02</td>
<td>0.18</td>
</tr>
<tr>
<td>% Decrease</td>
<td>62%</td>
<td>18%</td>
<td>47%</td>
<td>67%</td>
<td>46%</td>
</tr>
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</table>

During the eight-month test period, 16,077 tons of oat hulls were consumed, displacing 8,065 tons of coal. If the maximum oat hull burn rate of 10.5 tons per hour was sustained for 8,000 hours per year of operation, 84,000 tons of oat hulls could be burned. However, there are a number of factors that dramatically reduce the actual burn rate. These factors include need to do maintenance on the boiler and fuel handling systems, very small oat hull storage silo, and a just in time oat hull delivery coordinated with the fuel burn rate.

The expected consumption rate for Boiler #11 is around 35,000 tons per year, displacing 23,000 tons of coal. Besides the substantial reductions of regulated air pollutants, green house gas emissions (carbon dioxide from fossil fuels) were reduced by 19,400 tons \(\text{CO}_2\) during the hull test, and expected to save 55,000 tons \(\text{CO}_2\) per year. This is a significant positive environmental impact. To further realize the magnitude of The University of Iowa Biomass Fuel Project, 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 University.

The University of Iowa is now reaping the reward of taking a risk with unproven technology. 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. The University and Quaker Oats have a long-term commitment to the viability of biomass energy. UI is now leading the way with its plans to design the next addition to the UI Power Plant: Boiler #12 is an institutional boiler engineered for biomass combustion.