DESIGNING AN OPPORTUNITY FUEL WITH BIOMASS AND TIRE-DERIVED FUEL FOR COFIRING AT WILLOW ISLAND GENERATING STATION AND COFIRING SAWDUST WITH COAL AT ALBRIGHT GENERATING STATION

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Principal Authors: K. Payette and D. Tillman

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Name and Address of Submitting Organization:

Allegheny Energy Supply Co., LLC.
4350 Northern Pike
Monroeville PA 15146-2841

DISCLAIMER

ABSTRACT

During the period January 1, 2003 –March 31, 2003, Allegheny Energy Supply Co., LLC (Allegheny) proceeded with improvements to both the Willow Island and Albright Generating Station cofiring systems. These improvements were designed to increase the resource base for the projects, and to address issues that came up during the first year of operations. This report summarizes the activities associated with the Designer Opportunity Fuel program, and demonstrations at Willow Island and Albright Generating Stations.

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INTRODUCTION

Cofiring—the firing of two dissimilar fuels at the same time in the same boiler—has been proposed for using biomass in coal-fired utility boilers. In practice, this cofiring introduces a family of technologies rather than a single technology. The family of technologies includes blending the fuels on the coal pile or coal belt, and feeding them simultaneously to any processing (e.g., crushing and/or milling) systems on their way to the boiler; preparing the biofuels separately from the coal and introducing them into the boiler in a manner that does not impact fossil fuel delivery; or converting the solid biofuels to some other fuel form (e.g., producer gas) for firing in a coal-fired or natural gas-fired installation. The Allegheny project is designed to demonstrate both direct combustion approaches to cofiring.

The Willow Island Demonstration

Allegheny Energy Supply, LLC will demonstrate blending wood waste and tire-derived fuel to create a new opportunity fuel for cofiring in cyclone boilers, and integrating this fuel combination with a separated overfire air system for maximum NO_x management. This project also will demonstrate the use of biomass-TDF blends to reduce SO_2 and fossil CO_2 emissions along with trace metal emissions. The demonstration will occur at Willow Island Generating Station Boiler #2. It is a 188-MW_e cyclone boiler operated in a pressurized mode and equipped with a “hot side” electrostatic precipitator (ESP). This demonstration, located in Willow Island, WV, has numerous unique features to significantly advance cofiring technology. Allegheny Energy, using Foster Wheeler Development Corporation, has completed a feasibility study for the project and has moved into Phase II—construction and operation of the demonstration system.

Cofiring of wood wastes with coal has been demonstrated as an effective means for using biomass in cyclone boilers; demonstrations have occurred at the Allen Fossil Plant of TVA, the Michigan City Generating Station of NIPSCO, and the Bailly Generating Station (BGS) of NIPSCO. In these demonstrations, NO_x, SO_2, and fossil-based CO_2 emissions reductions occurred. In each case, the volatility of the wood waste created the mechanism for NO_x reduction, while the use of a sulfur-free fuel reduced SO_2 emissions. Testing at BGS opened a new area of investigation: designing blends of opportunity fuels to optimize the impacts of cofiring. At BGS, urban wood waste is mixed with petroleum coke at a specified blend to optimize NO_x emissions management while accomplishing the goals of fossil CO_2 emissions reductions. The NO_x emissions reductions at BGS are ~30 percent when firing the designed opportunity fuel blend.

The Willow Island demonstration blends sawdust with TDF to create a new opportunity fuel for cofiring in a cyclone boiler equipped with a separated overfire air system. This demonstration evaluates the creation of a second opportunity fuel blend that has potential to maximize NO_x emissions reductions from the combustion process. At the same time, SO_2 emissions are reduced along with fossil CO_2 emissions and heavy metal emissions. The Willow Island plant "hot-side" ESP requires the use of a sodium additive to enhance the resistivity of the flyash particles. This demonstration examines the potential of biofuel cofiring to obviate the need for such additives in the control of particulates and opacity—capitalizing upon the potassium and sodium content of the biomass ash.

The demonstration program involves optimizing the sawdust-TDF-coal blend for maximum impact in the cyclone combustion process. Further, it involves optimizing this blend to capitalize upon the overfire air system for NO_x management. It is estimated that the project will fire at least 10 percent wood waste, along with about 10 percent TDF in the project.

While this demonstration involves integrating past successful programs, it provides a significant enhancement of cofiring and the use of biomass. If successful, it will be the first demonstration where cofiring has been explicitly integrated into an overall NO_x control strategy as a significant contributor. Further, if successful, it provides a means for cyclone boiler owners and operators to consider NO_x management strategies other than end-of-pipe solutions or expensive fossil-based combustion strategies to achieve compliance with current and proposed regulations.

Further, this will be the first cofiring demonstration where the boiler is equipped with a "hot side" electrostatic precipitator—an ESP installed between the economizer and the air heater rather than after the air heater. Such "hot side" ESP's conventionally use sodium additives to improve the resistivity of the flyash and enhance its capture. Biomass, with its concentrations of potassium and sodium, may reduce or eliminate the need for such additives. This demonstration will address that condition and, as a consequence, advance the use of cofiring in coal-fired boilers.

The Albright Demonstration

The Albright Generating Station demonstration provides a means for comparing the NO_x reduction results obtained at Willow Island Generating Station—in a cyclone boiler—to those that can be obtained in a pulverized coal boiler. The Albright Generating Station Boiler #3 is a 140 MW_e boiler, comparable in capacity to the Willow Island boiler. It burns a similar eastern bituminous coal. Of critical importance, the Albright boiler is equipped with a low-NO_x firing system including a separated overfire air system.

The Electric Power Research Institute (EPRI) has developed a demonstration of sawdust cofiring in a PC boiler at the Seward Generating Station. A favorable biomass fuel supply potential and the favorable technology potential has led Allegheny to decide to relocate the cofiring demonstration to the Albright Generating Station. The relocation of the separate injection demonstration from Seward Generating Station to Albright provides opportunities to extend the knowledge base concerning cofiring—capitalizing upon the configuration of Albright Boiler #3. Specifically cofiring has not been applied to a generating station equipped with low NO_x firing separated overfire air system. In relocating the demonstration from Seward to Albright, Allegheny Energy and USDOE have capitalized upon such an opportunity.

The Combined Results

The combination of the Willow Island demonstration at the cyclone boiler and the comparative data developed at the Albright demonstration in a tangentially-fired pulverized coal boiler will provide definitive data concerning the emissions reduction potential of biomass cofiring in units already equipped with low NO_x firing systems. As such, these data will help define the potential, and limits, of biomass cofiring as an emissions reduction strategy. At the same time these demonstrations will provide a means for evaluating biomass cofiring as a cost-effective strategy for voluntary fossil CO_2 emissions reductions. Finally these projects will demonstrate additional environmental benefits of cofiring.

EXECUTIVE SUMMARY

The Eleventh Quarter of the USDOE-Allegheny Energy Supply Co., LLC (Allegheny) Cooperative Agreement, January 1, 2003 through March 31, 2003, was characterized by pursuing improvements to the Willow Island and Albright cofiring sites. Technical work that proceeded during the eleventh quarter of the cooperative agreement included the following:

- At Willow Island Generating Station, short term testing indicated the need for numerous minor modifications including improvements both to the sawdust receiving and processing area, and improvements to the walking floor bin.

- Allegheny, after evaluating the sawdust supply for the Albright Generating Station and determining the need for an oversized material grinder, completed detailed engineering and procurement for the installation of a new grinder. The grinder selected was a 2-stage grinder, to be installed at the discharge of the oversized particles from the screen. The grinder was ordered from Industrial Biomass, Inc.

- Papers were presented at the Electric Power Conference in Houston, TX, and at the Clearwater Conference, summarizing the progress at the Willow Island and Albright demonstrations.

- Progress anticipated for the twelfth quarter of this cooperative agreement—April 1, 2003 through June 30, 2003—includes continuation of the demonstration phase of the Willow Island project, installation of the 2-stage grinder at Albright, and new testing at the Albright Generating Station.

EXPERIMENTAL

Does not apply

RESULTS AND DISCUSSION

Overall results include significant operational testing at Willow Island, and the initiation of modifications to the Albright Generating Station Cofiring System.

Results at Willow Island

The cofiring system being installed at Willow Island is based upon blending the sawdust with TDF and coal in the bunkers, and feeding the blended fuel to the cyclones. Sawdust is received in walking floor vans. They deposit the sawdust into a receiving hopper. From there the sawdust is conveyed to a disc screen for processing. The screen produces a product at <¼" x 0" particle size for maximum NO_x benefit. Screened product is conveyed to a large live bottom bin for storage. It is reclaimed from the bin and deposited on the main conveyor belt feeding coal to the bunkers. Blending the sawdust with the coal and TDF is accomplished by 3 transfer points and by passing the blend through the secondary crushers. Oversized product from the screen is sent to a small grinder that reduces the particles to <1" and then integrates them with the product of the disc screen.

In the processing building, the receiving hopper was modified to reduce dust emissions. Plexiglass barriers and dock seals were added, along with a stop/go light to improve truck unloading while minimizing dust emissions at that point. Figure 1 depicts this change.

Figure 1. The improved sawdust receiving system including plexiglass barriers and dock seals.

Skirting was added for the conveyor of the acceptable product underneath the disc screen. This skirting reduced dust emissions from the screening operations.

New 1" screens were added to the Cresswood grinder for oversized particles, replacing the ? " screens installed previously. The Cresswood grinder suffered from low capacity, and a tendency of the screens to plug with wet sawdust. The new, larger, screens are designed to resolve that problem. Because Willow Island is a cyclone boiler, with secondary fuel crushers at the outlet of the bunkers, using larger biomass particles will not compromise the operations of the unit.

The angle of the reject chute at the head end of the disc screen was changed to reduce plugging and consequent dust generation.

Improvements to the walking floor bin were also made. A change was made in the ratio of the walking floor speed and the discharge auger speed. The discharge augers are now always operated in a flooded condition in order to avoid surges in biomass flow to the main coal belt, and consequent inconsistent fuel blending.

The positioning of the level detection system has been adjusted to prevent stoppage of the walking floor due to accidental coverage.

A purge cycle has been added to the augers such that, at the end of any day loading biomass on to the coal belt, the augers are completely clear of sawdust. This prevents system failure due to sawdust freezing overnight.

The collective result of these improvements has been increased flexibility and operability of the biomass cofiring system at Willow Island Generating Station.

Results at the Albright Demonstration

The Albright program requires some modification to continue. During the eleventh quarter, additional engineering was completed pursuant to the installation of a grinder to process oversized equipment. A 2-stage grinder was procured from Industrial Biomass, Inc. Fabrication of the grinder commenced and was largely completed during this quarter.

CONCLUSION: Expected Technical Progress During the 12th Quarter

The tenth project quarter, from April 1, 2003 through June 30, 2003 is expected to see the following progress, as shown in Table 1.

Table1. Anticipated Progress at Willow Island and Albright Demonstration Sites

Progress at Willow Island	Progress at Albright
Demonstration of cofiring to continue, and data analysis associated with the demonstration	Completion of 2-stage grinder fabrication, and delivery of grinder to site.
Submittal of abstract to Pittsburgh Coal Conference concerning cofiring at Willow Island and Albright Generating Station	Installation of 2-stage grinder, and resumption of cofiring testing coupled to new low NO_x firing system installed by Foster Wheeler.
	Submittal of abstract to 2004 Clearwater Conference on conclusion of cofiring testing at Allegheny Energy.

REFERENCES

None

APPENDIX: Conference Papers Presented at Electric Power Conference and Clearwater Conference

Cofiring Woody Biomass at Allegheny Energy: Results from Willow Island and Albright Generating Stations

David A. Tillman
Foster Wheeler Power Group, Inc.

Kathleen Payette
Tim Banfield
Allegheny Energy Supply Co., LLC.

Sean Plasynski
National Energy Technology Laboratory
US Department of Energy

Abstract

Allegheny Energy Supply Co., LLC, with support from the US Department of Energy (USDOE) National Energy Technology Laboratory (NETL) and the Office of Energy Efficiency and Renewable Energy (EERE), has constructed and operated two cofiring demonstrations at the Willow Island Generating Station and at the Albright Generating Station. This program has demonstrated cofiring at both a 188 MW cyclone boiler and at a 140 MW tangentially fired (T-fired) pulverized coal boiler. Between the two units, more than 6,000 tons of sawdust have been fired with Eastern bituminous coals. In the case of Willow Island, cofiring was performed with tire-derived fuel (TDF) as well. These 6,000+ tons of sawdust represent generation of nearly six million kWh of renewable energy; and they represent a total reduction in greenhouse gas emissions equivalent to some 18,000 tons of fossil CO_2. The Willow Island program was designed to develop a designer opportunity fuel combining sawdust with TDF to achieve a highly volatile, low nitrogen and low sulfur opportunity fuel for cyclone firing. The Albright program was designed to test the cofiring of sawdust in a pulverized coal boiler equipped with close coupled overfire air (CCOFA) and separated overfire air (SOFA) to evaluate the ability of biomass to reduce NO_x emissions in a boiler with low-NO_x firing capability. Both test programs have been successful. This paper reviews the operational and environmental results of both programs, providing an evaluation of biomass cofiring as a fuels-based tool for addressing environmental issues including NO_x, SO_2, and mercury emissions. It addresses future test programs that are planned for these units as well.

0.0. Introduction

Allegheny Energy Supply Co., LLC., supported by the National Energy Technology Laboratory (NETL) and the Office of Energy Efficiency and Renewable Energy (EERE) of USDOE, has implemented cofiring at two generating stations: Willow Island Generating Station and Albright Generating Station. In both cases the objective of cofiring was to generate cost-effective and environmentally friendly renewable energy.

This objective included reducing airborne emissions including mercury, SO_2, and NO_x. The focus of the Willow Island project included integrating sawdust with tire-derived fuel to achieve a designer opportunity fuel. This followed the work at Bailly Generating Station, where urban wood waste was blended with petroleum coke to achieve a highly desirable opportunity fuel (Tillman, 2001). The focus at Albright Generating Station was to integrate the practice of cofiring with the use of separated overfire air (SOFA) to achieve a combined approach to NO_x reduction.

Both installations have been installed and have been operated as test and demonstration units for a significant period of time. The Albright cofiring system shown in Figure 1 was relocated from Seward Generating Station in the first and second quarters of 2001. It was tested extensively in the third and fourth quarters of 2001, and periodically in 2002. Selected results from this installation have been reported previously (see, for example, Tillman et. al. 2002a; Tillman, 2001). The Willow Island cofiring system shown in Figure 2 was designed and installed in 2001 and the first quarter of 2002. Its design and installation have been reported previously (see Tillman et. al. 2002b). The Albright system focuses upon separately injecting the sawdust into the pulverized coal boiler while the Willow Island system focuses upon adding sawdust to the coal on the main belt leading to the bunkers feeding the cyclone burners.

Figure 1. Cofiring Installation at Albright Generating Station. Housed in the structure are the fuel receiving, screening, metering, and pneumatic transport systems.

Figure 2. Cofiring Installation at Willow Island Generating Station. This installation includes fuel receiving, screening, and grinding of oversized particles in the main building (shown), and fuel storage, reclaim, and metering (to the main belt) in the walking floor bin (not shown).

Both of these systems were designed to be robust—to withstand commercial operating conditions and to be operated with a minimal labor and maintenance commitment. Further, both of these systems were designed with multi-year design lives, consistent with obtaining operating and maintenance experience relevant to commercial rather than test systems.

1.0. Results at Willow Island Generating Station

The first year of cofiring at Willow Island Generating Station has involved more than 2000 hours of firing sawdust and sawdust/TDF mixtures. As such, it has demonstrated that there are no negative impacts on boiler capacity, only minor impacts on boiler efficiency, potentially positive impacts on combustion and furnace temperatures, and favorable impacts on fuel costs. Approximately 4,000 tons of sawdust have been burned, generating about 3,800 MWh of renewable energy and reducing fossil CO_2 emissions by more than 12,000 tons (CO_2 equivalent).
Operational results from cofiring sawdust, and combinations of sawdust and TDF, included the influences of these fuels on the ability of the unit to make capacity, to

operate in an efficient manner, to achieve desired temperatures, and to impact fuel costs. In all of these cases the cofiring system met or exceeded expectations.

As expected, the cofiring of sawdust modestly increased the use of boiler feeder capacity as is shown in Figure 3. The sawdust, having both a lower calorific value, and a lower bulk density, speeds up the feeders to the cyclones. However the increases in feeder speeds never caused the unit to experience a capacity limitation.

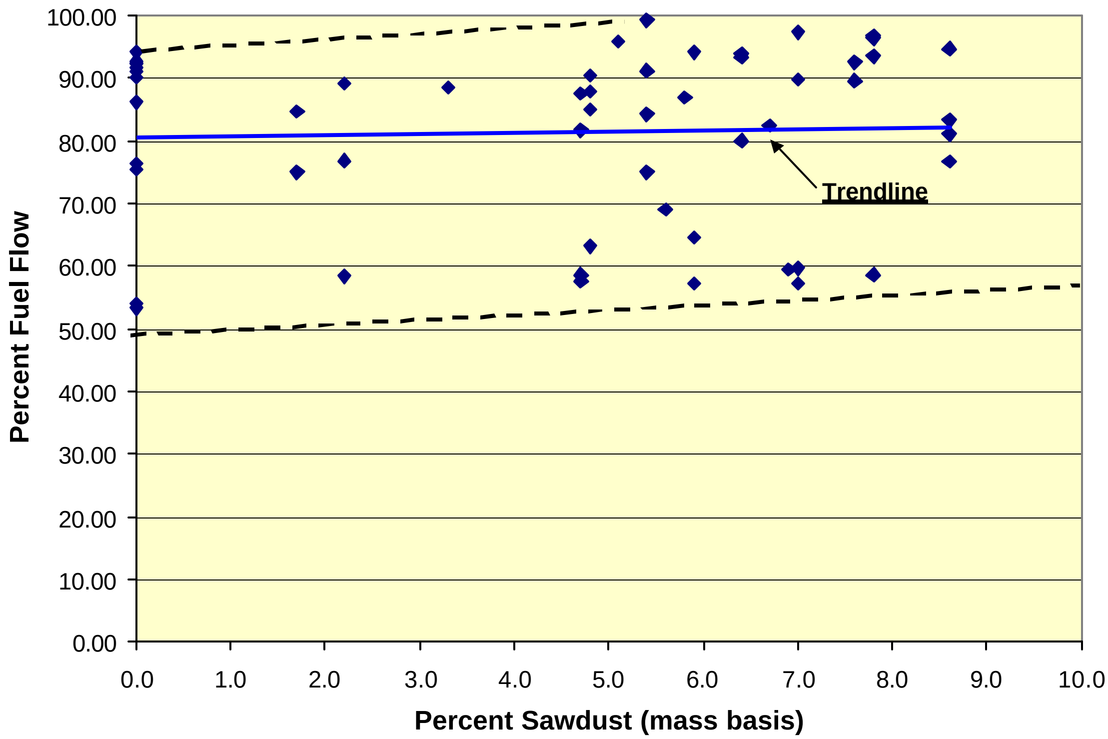

Figure 3. The Influence of sawdust cofiring on fuel feeding capacity

Because the fuel feeding capacity is a function of both fuel quality (Btu/ft^3 of fuel) and load, a simplified regression equation was created as shown below:

$$CF = 2.281 + 0.505(\%W) + 0.462(MW_g) \quad [1]$$

Where CF is percentage coal flow, %W is percent sawdust cofiring on a mass basis, and MW_g is the load expressed in gross megawatts generated. The coefficient of determination (r^2) for this equation is 0.96. The probability that the %W term occurs randomly is 0.00014 and the probability that the influence of load occurs randomly is 6.2×10^{-40}.

The impact of cofiring on system efficiency includes both boiler efficiency, expressed as a percentage, and net station heat rate expressed as Btu/kWh. Evaluations of efficiency include both assessments of specific operating parameters—excess O_2 or stoichiometric ratio (SR), air heater exit temperature, and loss on ignition—and on efficiency as a whole. Boiler efficiency was evaluated by calculating a heat and material balance about the boiler for each test. Heat and material balances were calculated using molar calculations and the "losses" methodology. The overall influence of sawdust cofiring, and sawdust/TDF cofiring, on boiler efficiency is very small. Regression analysis shows that the maximum degradation in boiler efficiency caused by cofiring is 0.03 percent efficiency loss/percent wood cofiring on a mass basis. When cofiring at 10 percent (mass basis) the maximum efficiency loss would be 0.3 percent. The regression analysis was not robust, however; variability in the coal being fed, along with other factors, contributed to a low coefficient of determination. The influence of specific parameters on efficiency became significant for analytical purposes. Factors analyzed included excess O_2 or stoichiometric ratio, air heater exit temperature, loss on ignition, and then selected components of the losses calculation: dry gas loss, fuel moisture content, and hydrogen content in the fuel.

Excess O_2 at the furnace exit, or stoichiometric ratio (SR) for combustion, was the first variable analyzed. The percentage wood and the percentage TDF in the fuel blend has virtually no influence on the SR. Cofiring also does not influence the air heater exit temperature. If anything, there was a slight (favorable) downward trend in air heater exit temperature as a function of sawdust cofiring. That trend is not significant, however; essentially there is no influence. Further, the inclusion of sawdust into the fuel blend had no influence on unburned carbon in the flyash, or loss on ignition (LOI).

The heat and material balances for operations above 177 MW_e gross load were used to evaluate the influences of dry gas loss, moisture in the fuel, and hydrogen in the fuel. These cases indicate that the influence of sawdust and TDF is the increase in moisture in the fuel and hydrogen in the fuel. The latter results from the higher hydrogen/carbon atomic ratios associated with the sawdust and the TDF. These accounted for the 0.03 percent decrease in boiler efficiency for every percent (mass basis) sawdust included in the fuel feed. TDF had even less impact on boiler efficiency.

The overall impact of cofiring on net station heat rate (NSHR) is not readily apparent from operating data; the influences are quite minor. Of significance to the heat rate determination is the influence of cofiring on main steam temperatures. Cofiring did not reduce main steam temperatures when operating at any condition. In virtually all cases the main steam temperature was between 1000^oF and 1020^oF, regardless of fuel blend or load. Hot reheat steam temperatures also were not influenced by cofiring sawdust or sawdust/TDF blends as well. The only method for analyzing the impact on net station heat rate, then, is to analyze based upon a theoretical turbine heat rate and apply the boiler efficiency to that. Overall, it was calculated that there would be an increase in NSHR of 32 Btu/kWh when cofiring sawdust at 10 percent (mass basis). As a practical matter, the measurements made do not provide sufficient information to quantify this with test data.

Both flame temperatures (T_f) and furnace exit gas temperatures (FEGT) are of concern when cofiring sawdust and sawdust/TDF blends. Flame temperatures are essential to maintaining the slag in a condition where it will readily flow through slag taps to slag tanks. FEGT significantly influences deposition of inorganic matter in the boiler—and particularly influence where that deposition will occur.

Flame temperatures experienced minimal impact from cofiring activities. T_f values are not readily measured directly, however they can be calculated using the combustion code developed by NASA. These calculations employ Gibbs Free Energy minimization calculations to account for dissociation of CO_2 into CO and O, and other similar high temperature reactions. Theoretical and estimated actual flame temperatures have been calculated for 10 full load cases where the sawdust cofiring ranged from 0 to 9 percent (mass basis), and the TDF cofiring ranged from 0 to 6 percent (mass basis). These cases are shown in Table 1.

Table 1. Estimated Flame Temperatures for Full Load Firing at Willow Island

Case		Load	% Cofiring		Theoretical T_f		Est. Actual T_f	
Date	Time	(MW)*	Sawdust	TDF	K	^oF	K	^oF
03/11	0304	194.71	0	6	2335.1	3744.2	2100	3325
07/02	1826	183.52	3	0	2345.4	3762.7	2110	3340
07/23	1738	183.00	4	0	2349.5	3770.1	2115	3350
08/02	2000	190.14	0	0	2356.2	3782.2	2120	3360
09/20	0935	189.44	7	4	2355.5	3780.9	2120	3355
09/22	1730	184.05	6	3	2346.0	3763.8	2110	3340
09/23	1620	188.07	6	5	2357.9	3785.2	2122	3360
10/10	0954	188.81	8	0	2342.9	3758.2	2110	3335
10/30	0906	189.52	8	0	2356.6	3782.7	2120	3360
11/04	0911	189.48	9	0	2350.7	3772.3	2115	3350
* Gross Megawatts electric generated								

Note that there is very little variation in flame temperature as a function of fuel at full load. Two regression equations have been constructed to estimate flame temperature at Willow Island #2 boiler, as shown below:

$$T_f = 3670 + 5.9*(\%C) + 4.8(\%W) + 6.2(\%TDF) + 3.7(\%L) – 617(SR) + 0.38(T_{air}) \quad [2]$$

And

$$T_f = 4248 – 579(SR) + 0.30(T_{air}) \quad [3]$$

Where T_f is theoretical flame temperature (^oF), %C is percent coal in the fuel blend (mass basis), %W is percent sawdust in the fuel blend (mass basis), %TDF is percent tire-derived fuel in the total fuel blend (mass basis), %L is percent limestone in the total fuel blend (mass basis), SR is stoichiometric ratio, and T_{air} is temperature of the combustion air (^oF). Theoretical flame temperatures, rather than estimated actual flame temperatures, were used for these calculations because theoretical flame temperatures are the basis for estimating actual flame temperatures. The r^2 for equation [2] is 0.999 and the r^2 for equation [3] is 0.937. Interestingly, the calculation of the significance values for the biomass and TDF fuel variables shows that these are not significant contributors to flame temperature. The higher moisture biomass has little impact on flame temperatures despite its lower calorific value and its higher moisture content. The reason is fuel volatility and the consequent rate of weight loss. Shafizadeh and DeGroot (1977) developed the necessary explanatory equation as shown below:

$$F_i = (dw/dt)h \quad [4]$$

Where F_i is flame intensity, dw/dt is the rate of weight loss of a sample of fuel with respect to time, when being subjected to Thermogravimetric analysis (TGA) at a heating rate of 20^oC/min, and h is the heat content of the fuel (cal/g). This equation shows that, while the biomass fuels are lower in calorific value and higher in moisture, the rate of weight loss resulting from their high volatility is sufficient to compensate and to generate high flame temperatures. Consequently, in all cases tested at the Willow Island Generating Station #2 boiler, the flame temperatures were sufficient to support good slag formation. In no case was the flame temperature compromised by the practice of cofiring.

The practice of cofiring at Willow Island caused a decrease in FEGT as is shown in Figure 4. Note the trend shown in this figure based upon sawdust addition.

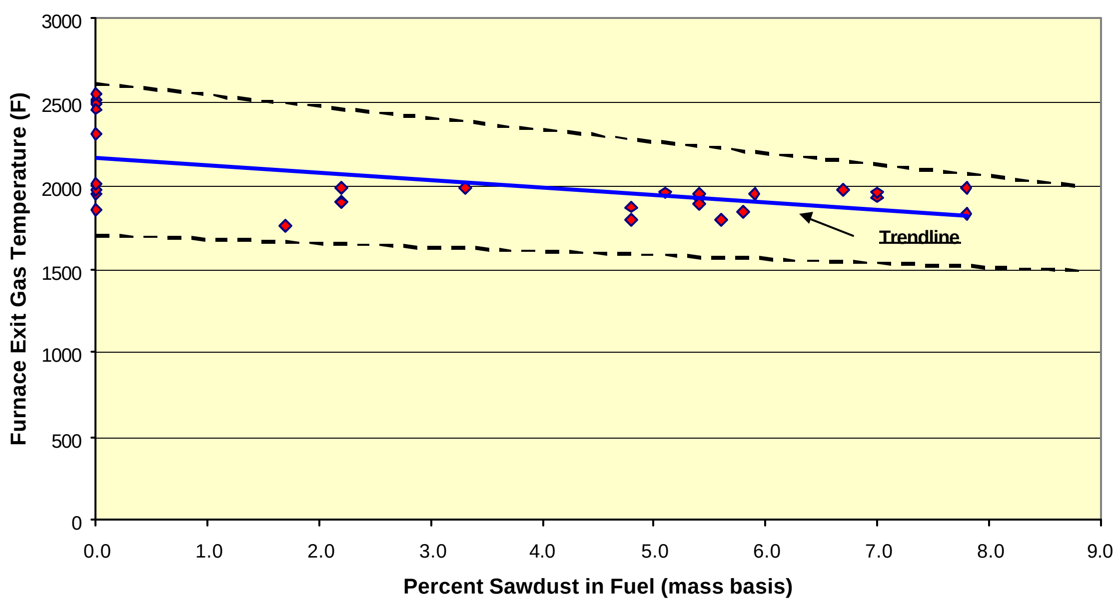

Figure 4. The Influence of sawdust cofiring on furnace exit gas temperature

Note that the trend is quite flat as the percent sawdust exceeds 5 percent. It is useful to observe that, while this trend occurred, the main steam and reheat steam temperatures did not decrease as well. That was caused by a modest increase in flue gas volume when sawdust was added to the fuel blend.

Operationally, then, the cofiring project has demonstrated benefits without incurring significant capacity, efficiency, or temperature penalties.

Cofiring sawdust and TDF has the potential to accomplish environmental benefits for Willow Island Generating Station. Specific considerations include SO_2 reduction, NO_x reduction, mercury reduction, and greenhouse-gas reduction.

Biomass cofiring reduced SO_2 emissions; sawdust is virtually sulfur-free. Figure 5 summarizes the SO_2 emissions as a function of biomass cofiring. Note that there is a trend towards SO_2 reduction; however there is significant scatter in the results as a consequence of natural variability in the coal being burned.

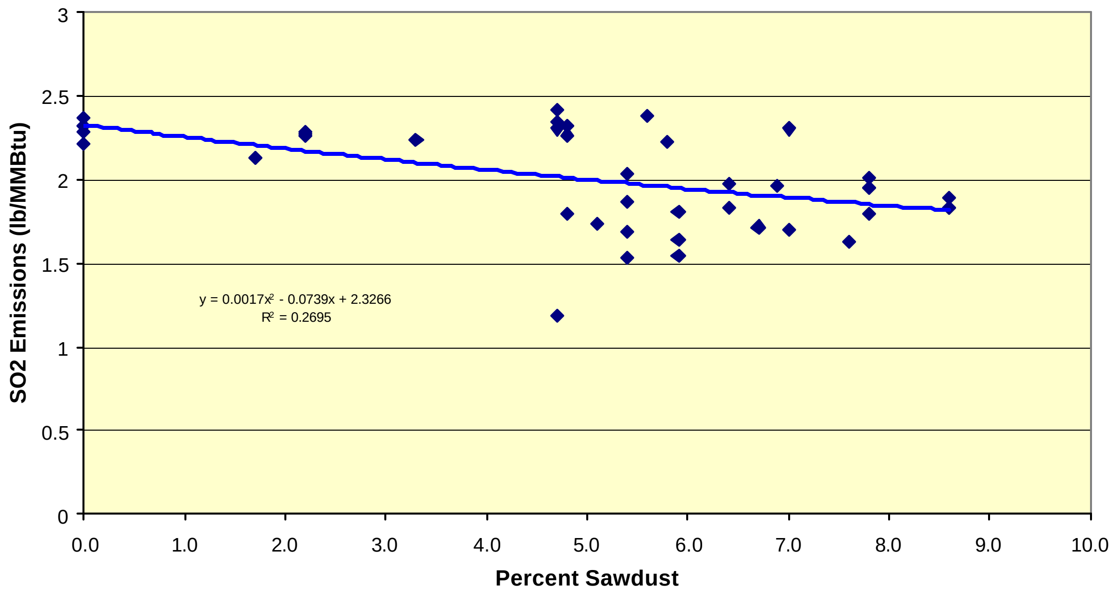

Figure 5. SO_2 Emissions as a function of sawdust cofiring at Willow Island

Cofiring sawdust, and combinations of sawdust and TDF, did not achieve the expected reductions in NO_x emissions. The sawdust and TDF both reduced the fuel nitrogen entering the cyclone barrel. The sawdust and TDF did not increase, or decrease, flame temperatures significantly but they did decrease FEGT. NO_x data showed significant variability, and regression analysis yielded no robust equations. Variability in NO_x emissions could well be a function of the inherent variability of the coal. The conclusion was that cofiring did not reduce, or increase, NO_x emissions.

Careful testing of the sawdust being fired at Willow Island Generating Station shows that the sawdust contains 0.003 – 0.009 mg/kg of mercury. This compares to 0.18 mg/kg of mercury in the coal, as reported in the Toxic Release Inventory (TRI) data. Cofiring reduces mercury emissions by reducing the feed of mercury to the boiler. Opacity and CO emissions were not impacted by cofiring at Willow Island Generating Station.

It has been shown that cofiring reduces fossil CO_2 emissions directly by 1.0 – 1.1 tons CO_2/ton biomass burned. Further, it has been shown that cofiring reduces fossil CO_2 equivalent emissions by an additional 2 tons for every ton of sawdust burned in a power plant, avoiding methane formation in landfills and other land applications. The cofiring of sawdust at Willow Island has reduced greenhouse gas emissions by >4,000 tons CO_2 directly, and by a total of more than 12,000 tons fossil CO_2 equivalent in the year 2002. Since Allegheny Energy has committed to a voluntary reduction of greenhouse gases, this project has contributed to the overall corporate target.

2.0. Cofiring Results at Albright Generating Station

The testing at Albright Generating Station demonstrated that biomass cofiring—using separate injection—could minimally impact operations while reducing airborne emissions. Significantly the PC boiler at Albright, at 140 MW_e, is comparable in capacity to the 188 MW_e cyclone boiler at Willow Island.

Testing at the Albright Generating Station involved the consumption of more than 2,000 tons of sawdust in a unit equipped with a separated overfire air (SOFA) system. The biomass resulted in generation of approximately 1,700 MWh of green—renewable—power. It accomplished the reduction of more than 6,000 tons of fossil CO_2 (equivalent) greenhouse gas.

Testing at the Albright Generating Station occurred in short (e.g. less than eight-hour) tests along with a 100-hour performance test to determine the reliability of the cofiring system. Both the short term and the 100-hour tests were highly successful. The cofiring did not compromise boiler capacity despite testing during summer capacity alerts. The cofiring did not compromise the performance of the induced draft (ID) fan, the system most susceptible to problems associated with cofiring on hot days. The impact of cofiring on boiler and unit efficiency was comparable to that experienced by Willow Island; for every 10 percent cofiring (mass basis), the unit incurred a NSHR penalty of 35 Btu/kWh.

Emissions reductions occurred in all tested airborne emissions areas: SO_2, NO_x, and mercury. SO_2 was reduced proportional to the percentage cofiring based upon heat input; when cofiring at 10 percent (mass basis) the equivalent cofiring level based on a Btu basis was 4.7 percent. SO_2 emissions were reduced by >4.5 percent under those circumstances.

The practice of cofiring at the Albright Generating Station caused a significant reduction in NO_x emissions measured in lb/10^6 Btu as shown in Figure 6. Note the substantial spread in the data, caused by natural variations in the following parameters: instantaneous coal composition, cofiring percentage, excess O_2, and SOFA positions. Within the load range tested, load did not appear to be a significant contributor to the formation or control of NO_x. In general, cofiring at 10 percent by mass (4.7 percent by heat input) caused about a 15 percent reduction in NO_x, measured in lb/10^6 Btu. In other words, for every percent sawdust fired on a heat input basis, NO_x was reduced by ≥ 3 percent. NO_x emissions were consistently measured as low as 0.25 lb/10^6 Btu when cofiring and maximizing the use of the SOFA system.

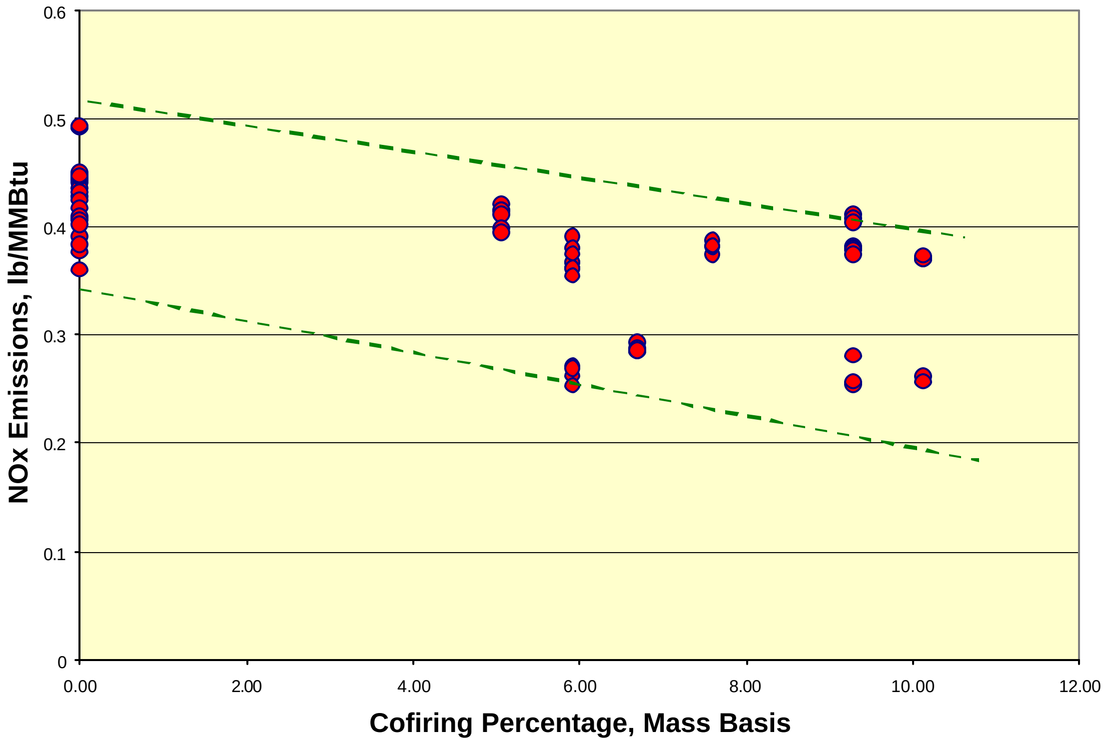

Figure 6. NO_x reduction during cofiring testing at the Albright Generating Station

The data generated during the testing were converted into a single robust regression equation as shown below. The equation was based upon 68 individual data points. The r^2 for this equation is 0.873.

$$NO_x\ (lb/10^6\ Btu) = 0.361 - 0.0043(W\%) + 0.0217(O_2\%) - 0.00055(SOFA) \qquad [5]$$

Where NO_x is measured in $lb/10^6$ Btu, W% is sawdust percentage in the fuel on a mass basis, O_2% is the percentage excess oxygen measured at the furnace exit, and SOFA is the total percentage of the three SOFA dampers expressed as percent open. Note that the range of W terms is 0 – 10, the range of O_2% terms is 2.8 – 4, and the range of SOFA terms is 15 – 240. This may explain the difference in the coefficients. The equation is quite robust; all parameters measured were subjected to statistical testing to determine whether the specific term could have occurred as a random event. The probability that any term could occur as a random event was, in all cases, $<1x10^{-4}$.

Interestingly, the cofiring not only reduced NO_x emissions directly, but also supported increased use of the SOFA system. Testing demonstrated that the SOFA dampers could be opened to a wide-open position without compromising unburned carbon in the flyash. This resulted from volatility in the sawdust compared to coal. Mercury emissions reductions occurred in a manner that was virtually identical to that associated with cofiring at Willow Island Generating Station. Opacity and CO emissions were not impacted by cofiring.

4.0. Conclusions

The cofiring program at Willow Island and Albright has been successful in demonstrating the long-term viability of this approach as a low-cost approach to generating significant amounts of renewable and environmentally friendly electricity. In cofiring over 6,000 tons of woody biomass, Allegheny has generated about 5,500 MWh—5,500,000 kWh—of renewable power. At the same time Allegheny has reduced greenhouse gas emissions by more than 18,000 tons of fossil CO_2 (equivalent) by displacing coal, and by using the biomass in the most environmentally friendly and efficient manner. SO_2 emissions have been consistently reduced, and NO_x emissions were reduced in the case of Albright Generating Station. Mercury emissions were reduced while opacity and CO emissions were not impacted.

The operational data show that the environmental benefits were achieved without a significant efficiency penalty, measured in NSHR, and without any capacity penalty. These two test programs will be continued. Incremental improvements are being made continuously at Willow Island Generating Station. A new grinder is being installed to facilitate operations at Albright Generating Station. These programs illustrate, with experience, the potential of woody biomass cofiring as a significant and cost-effective approach to generating environmentally friendly electricity.

5.0. References

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