Progress Report: Cofiring Projects for Willow Island and Albright Generating Stations

Prepared by:

Allegheny Energy Supply
an Allegheny Energy company

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

Quarterly Technical Report

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ABSTRACT`

During the period April 1, 2001 – June 30, 2001, Allegheny Energy Supply Co., LLC (Allegheny) accelerated construction of the Willow Island cofiring project, completed the installation of foundations for the fuel storage facility, the fuel receiving facility, and the processing building. Allegheny received all processing equipment to be installed at Willow Island. Allegheny completed the combustion modeling for the Willow Island project. During this time period construction of the Albright Generating Station cofiring facility was completed, with few items left for final action. The facility was dedicated at a ceremony on June 29. Initial testing of cofiring at the facility commenced.

This report summarizes the activities associated with the Designer Opportunity Fuel program, and demonstrations at Willow Island and Albright Generating Stations. It details the construction activities at both sites along with the combustion modeling at the Willow Island site.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The Fourth Quarter of the USDOE-Allegheny Energy Supply Co., LLC (Allegheny) Cooperative Agreement, April 1, 2001 through June 30, 2001, was characterized by combustion modeling and project construction activities at both the Willow Island and Albright sites. Technical work that proceeded during the fourth quarter of the cooperative agreement included the following:

- At Willow Island Generating Station, combustion modeling was completed by N.S. Harding and Associates and Reaction Engineering International, using the fuels data developed by Pennsylvania State University (as reported previously). This modeling highlighted the combustion benefits of biomass—and the biomass/tire-derived fuel blend—with respect to cyclone firing.

- At Willow Island Generating Station, foundation construction was completed for the walking floor bin, the sawdust receiving facilities, and the processing building. These foundations have a combined total of >600 yd^3 of concrete.

- All sawdust processing equipment for the Willow Island facility has been received and is on-site, ready for installation.

- Construction was completed at the Albright Generating Station site. All of the equipment located at the Seward Generating Station was installed at the Albright site. The facility was then dedicated on June 29, 2001.

- Fuel procurement commenced for the Albright test. Loads of sawdust were received, processed, and stored in the silo. Three potential suppliers were placed under contract for sawdust supply.

- Baseline combustion testing was completed at the Albright Generating Station, providing a basis for analyzing cofiring tests.

- Initial shake-down testing commenced at the Albright site, indicating the need to increase the speed of the rotary airlocks, increase the size of the check valves, and the need to install a progressive auger for the truck unloader. Conditions also indicated the need for a building roof vent at Albright. Provisions for these items were made during the fourth quarter of the project.

Progress anticipated for the fifth quarter of this cooperative agreement—July 1, 2001 through September 30, 2001—includes completion of construction at the Willow Island Generating Station, and shakedown of that facility. Progress anticipated also includes significant activities pursuant to completing the detailed testing at the Albright Generating Station facility. The 720 hours of operational testing will also occur during this quarter.

1.0. 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.

1.1. 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 plans to move directly 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 will blend sawdust with TDF to create a new opportunity fuel for cofiring in a cyclone boiler equipped with a separated overfire air system. This demonstration will create a second opportunity fuel blend that maximizes NO_x emissions reductions from the combustion process and that can be integrated into the overall NO_x emissions management strategy using overfire air. At the same time, SO_2 emissions will be 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 will examine 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.

1.2. 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. This demonstration must be moved in order for it to be completed. Boiler #12, where sawdust has been fired, is now only maintained for capacity purposes and is not regularly fired. Boiler #15, which was intended as a site for cofiring, has an operating selective catalytic reduction (SCR) system essential to the operation of both Seward and Titus Generating Stations. Recent research by Elsamprojekt and Midkraft, supported by research of Sandia National Laboratories, has shown that biomass cofiring has the potential to be detrimental to SCR catalysts. Consequently the demonstration can no longer be operated at that site.

A favorable biomass fuel supply potential and the favorable technology potential has led Allegheny to consider relocating the cofiring demonstration to Albright. The relocation of the separate injection demonstration from Seward Generating Station to Albright Generating Station 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, it is prudent to capitalize upon such an opportunity.

Given this opportunity, Allegheny and Foster Wheeler will accomplish the following:

- Disassemble and remove the existing demonstration from the Seward site,
- Supply and install two biomass injectors in Albright Boiler #3
- Install piping sufficient to transport sawdust to the biomass injectors at Albright Boiler #3
- Install the process equipment removed from Seward Generating Station to the Albright Generating Station
- Construct a steel building to house the process equipment associated with the demonstration of separate injection cofiring
- Demonstrate cofiring at Albright, providing emissions data for comparison to the Willow Island demonstration.

1.3. 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.

2.0. TECHNICAL PROGRESS

Overall progress has included concluding contract negotiations with Foster Wheeler and, consequently, with the specialty subcontractors. With these contracts in place, progress has been significant on both projects.

2.1. TECHNICAL PROGRESS ON COMBUSTION MODELING AT WILLOW ISLAND GENERATING STATION

The fuels issues discussed in the Quarterly Report 40894r03 provide a basis for modeling combustion in the cyclone barrels and in the total cyclone boiler at Willow Island Generating Station. In review, Table 1 presents the proximate and ultimate analyses of the sawdust and coal fuels used at Willow Island, on a dry basis. It also presents the typical moistures for these fuels. Note that the compositions of the sawdust and coals are very similar to those previously reported for the biomass and fossil fuels to be burned at the Allegheny Energy Supply generating stations (see Tillman, Payette, and Battista. 2000).

Table 1. Composition of the Sawdust and Coals to be Burned at Willow Island

Parameter	Sawdust	Willow Island Coal(*)
Typical Moisture %	42.4	7.11
Proximate Analysis (wt %, dry basis)		
Ash	1.0	10.5
Volatile Matter	80.0	34.0
Fixed Carbon	19.0	35.5
Ultimate Analysis (wt %, dry basis)		
Carbon	49.2	76.7
Hydrogen	6.0	4.9
Oxygen	43.0	4.9
Nitrogen	0.8	1.4
Sulfur	<0.1	1.6
Ash	1.0	10.5
Chlorine (ppmw)	750	2200
Higher Heating Value (Btu/lb)	8400	13600

Note: (*): Includes addition of sodium chloride for “hot side” ESP performance support.

Critical to the modeling is the sieve analysis of the sawdust, as shown in Table 2. Note that the sawdust fired at Willow Island, like the sawdust fired at Albright, is dominated by fine particles with high surface/mass ratios. Such particles volatilize most rapidly, and combust most easily.

Table 2. Sieve Analysis of Sawdust

Particle Size	Percent Passing	Percent Retained on
¼"	100	0
1/8"	95.18	4.82
1/16"	48.49	46.69
1/32"	15.83	32.66
Pan	0	15.83

Based upon these data, and the excellent fuel characterization work of Pennsylvania State University including the kinetics presented in Quarterly Report 40894R03, extensive combustion modeling was performed by N.S. Harding & Associates and Reaction Engineering. The high quality combustion modeling addressed combustion completeness, temperatures, and NOx formation in the cyclone barrels and in the total cyclone-primary furnace system.

The following scenarios were modeled:

- Firing the Willow Island #2 boiler with 100 percent coal, and without the use of separated overfire air (SOFA)
- Firing the Willow Island #2 boiler with 100 percent coal, and with staged combustion using SOFA
- Firing the Willow Island #2 boiler with a blend of 85 percent coal, 10 percent sawdust, and 5 percent TDF (mass basis) without the use of SOFA
- Firing the Willow Island #2 boiler with a blend of 85 percent coal, 10 percent sawdust, and 5 percent TDF using SOFA
- Firing the Willow Island cyclones with a blend of 90 percent coal, and 10 percent sawdust
- Firing the Willow Island cyclones with a blend of 80 percent coal, 10 percent sawdust, and 10 percent TDF

The modeling itself is based upon the characteristics of the Willow Island cyclone barrels and the Willow Island primary furnace. The grids for these are shown in Figures 1 and 2.

Barrel Grid (60 x 65 x 62)

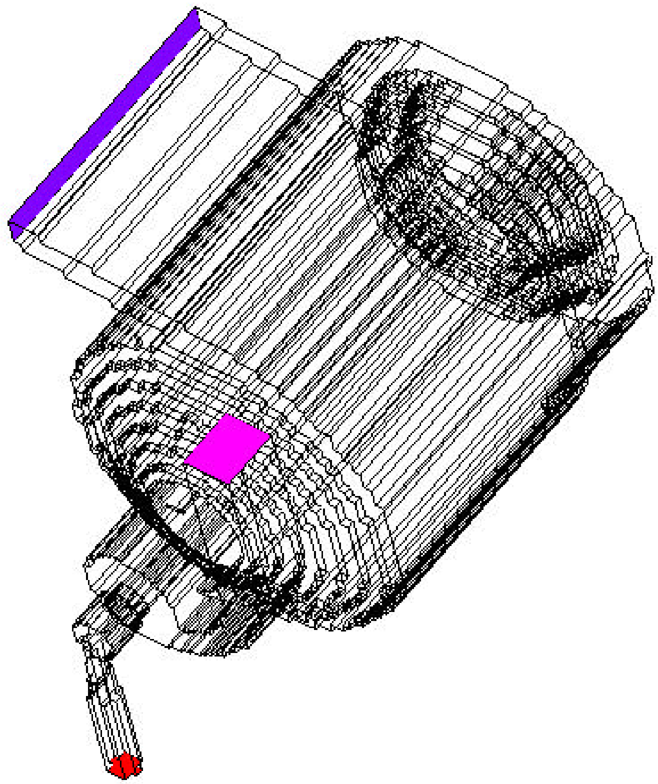

Figure 1. Depiction of the Willow Island Cyclone Barrels for Modeling Purposes
(Source: Reaction Engineering International)

Furnace Grid (126 x 43 x 125)

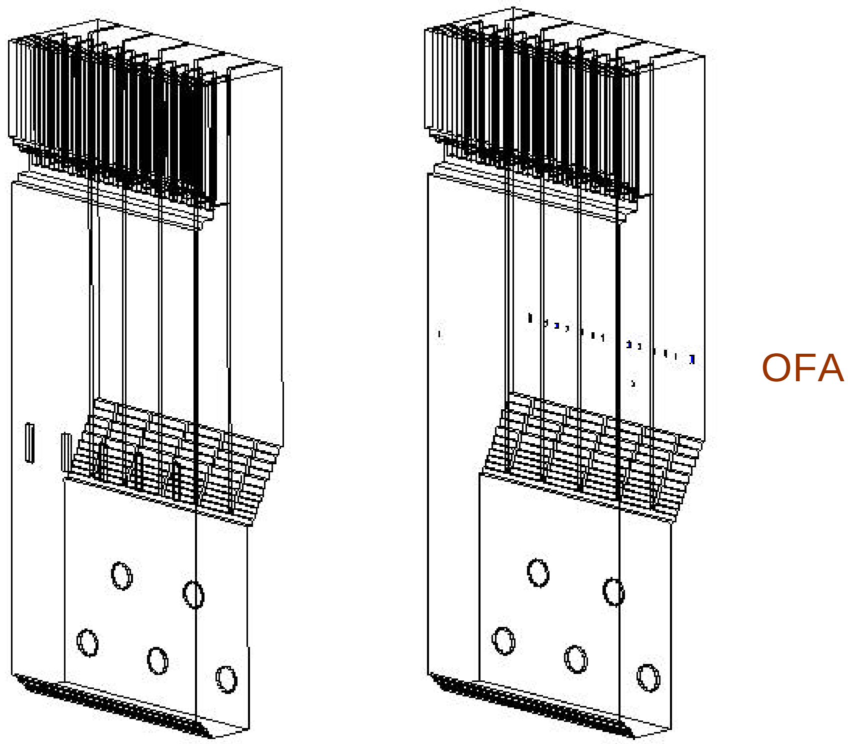

Figure 2. Depiction of the Willow Island Primary Furnace, With and Without SOFA, for Modeling Purposes.
(Source: Reaction Engineering International)

The results of the modeling performed without employing the SOFA system are summarized in Tables 3 and 4. Note that only one designer opportunity fuel blend is used in this modeling.

Table 3 Modeling Results Using the System Without Staged Combustion (SOFA)

Location	Parameter	Fuel Used	
		100% Coal	85% Coal/10% Sawdust/5% TDF
Cyclone Barrel	Exit Temperature (K)	1722	1794
	Exit Temperature (^{o}F)	2640	2770
	NO_x Concentration (ppmv, wet)	465	478
	NO_x Concentration (ppmv, dry)	493	511
	Particle Burnout (%)	94.2	96.5
Furnace	Exit Temperature (K)	1494	1498
	Exit Temperature (^{o}F)	2230	2236
	NO_x Concentration (ppmv, wet)	984	880
	NO_x Concentration (ppmv, dry)	1068	958

(Source: Reaction Engineering International)

Table 4. Cyclone Barrel Modeling Results Using Staged Combustion (SOFA)

	Fuel Blend			
Parameter	100% Coal	90/10*	85/10/5**	80/10/10***
Exit Temperature (K)	1750	1709	1759	1807
Exit Temperature (^{o}F)				
NO_x Concentration (ppmv, wet)	491	519	524	478
NO_x Concentration (ppmv, dry)	520	552	558	512
Particle Burnout (%)	94.3	96.0	95.6	96.2
* 90% Coal, 10% Sawdust				
** 85% Coal, 10% Sawdust, 5% TDF				
*** 80% Coal, 10% Sawdust, 10% TDF				

(Source: Reaction Engineering International)

The modeling of the 85/10/5 blend using staged combustion shows the following total system results:

- Furnace exit gas temperature: 1328 K

- Furnace exit gas temperature: 1930°F
- NO_x Concentration (ppmv, wet): 318
- NO_x Concentration (ppmv, dry): 347

The modeling results as summarized in tabular form do not totally present the combustion impacts of firing sawdust with coal, or a blend of sawdust and TDF with coal. Figure 3 shows a temperature profile of a cyclone barrel, resulting from the combustion modeling. Note that the blend of opportunity fuels not only increases the exit temperature from the cyclone barrel, it also increases the mixing in the cyclone barrel. The temperature is more uniform as well as hotter. This results in, and is reflected in, the improved combustion completeness shown in Tables 2 and 3.

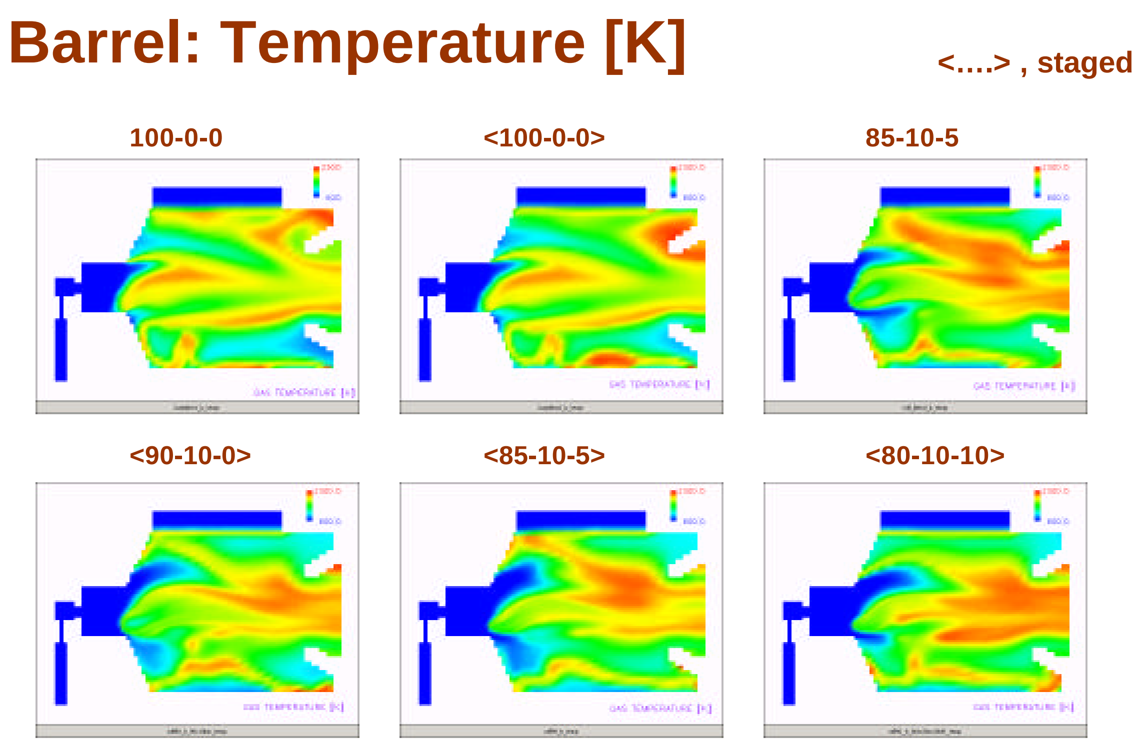

Figure 3. Temperature Profiles of the Cyclone Barrel When Firing Different Fuel Blends Under Unstaged and Staged Combustion Conditions.
(Source: Reaction Engineering International)

The temperature profiles demonstrate that the benefits of the volatility of the biomass, and the sawdust/TDF mixture, on combustion in the cyclone barrels. The NO_x benefits shown in the modeling (see, also, Figure 4) are a consequence of the fuel volatility, the interaction among fuels, and the combustion processes. Similarly the volatility enhances the completeness of combustion as shown in Tables 2 and 3.

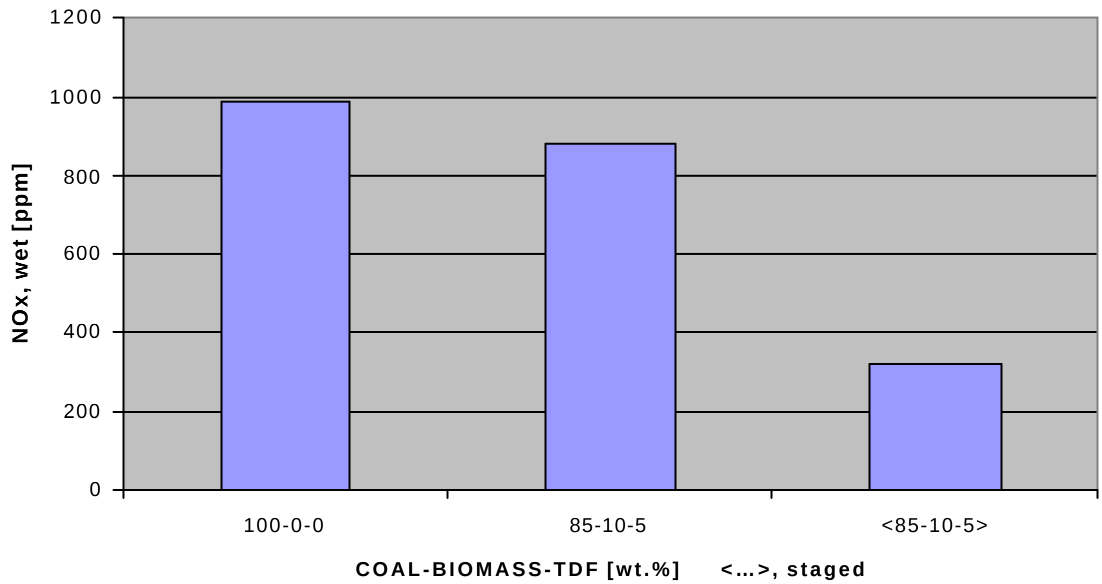

Figure 4. NO_x Emissions at the Furnace Exit, Documenting Benefits from Biomass and TDF Firing Under Unstaged and Staged Conditions.
(Source: Reaction Engineering International)

The modeling, then, documented the potential benefits of cofiring and designer opportunity fuel firing in the cyclone boiler at Willow Island Generating Station. The potential benefits in terms of mixing, combustion completeness, and NO_x emissions are well documented by this process.

2.2. CONSTRUCTION PROGRESS AT WILLOW ISLAND

The construction at Willow Island Generating Station included developing construction drawings for the entire project. It included pouring the foundations for the walking floor bin, the sawdust receiving pit, and the processing building.

Progress for the construction of the Willow Island project also includes receiving all processing and associated equipment as follows:

- Sawdust unloading hopper
- Sawdust unloading conveyor
- 50 ton/hr sawdust disc screen
- Disc screen outfeed conveyor
- Oversized particle grinder
- Processed sawdust conveyor (to the walking floor bin)

Allegheny Energy is most satisfied with this construction program. Figures 5 through 7 are pictures of the construction at Willow Island. They focus on the Walking Floor foundation and the sawdust receiving pit.

Figure 5. Forming the Walls of the Walking Floor Foundation

Figure 6. The Completed Walking Floor Foundation

Figure 7. Installing Rebar in the Sawdust Receiving Pit, Under Construction

2.3. TECHNICAL PROGRESS ON THE ALBRIGHT DEMONSTRATION

The Albright construction is essentially complete to the satisfaction of Allegheny Energy Supply Co., LLC. Figure 8 shows a completed project. Initial start-up and shakedown testing is also complete. This testing has indicated the need to replace and upgrade the check valves, replace the sprockets on the rotary feeders to increase their capacity, replace the outfeed auger on the walking floor unloader to a progressive auger in order to enhance truck delivery and unloading, install a roof vent on the building, and make other minor modifications.

Figure 8. The Completed Albright Generating Station Cofiring Project

The facility was dedicated at a ceremony on June 29, 2001. At this ceremony, David Benson, Vice President of Allegheny Energy Supply Co., Inc. dedicated the operation along with representatives of USDOE, Foster Wheeler, the Electric Power Research Institute, and various state and local agencies. A ribbon cutting ceremony was held (see Figure 9) to initiate cofiring at the Albright Generating Station.

Figure 9. Ribbon Cutting at the Albright Generating Station Cofiring Facility

2.4. EXPECTED TECHNICAL PROGRESS DURING THE FIFTH PROJECT QUARTER

The fifth project quarter, from July 1, 2001 through September 30, 2001 is expected to see the following progress, as shown in Table 5.

Table 5. Anticipated Progress at Willow Island and Albright Demonstration Sites

Progress at Willow Island	Progress at Albright
Completion of Construction including receipt of walking floor bin, receipt of MCC, installation of all equipment, and all associated activities	Detailed Testing for System Performance as a Function of Load and Cofiring Level
Baseline Testing	Maximum Cofiring Percentage Determination
Initial Startup and Shakedown Testing	100 Hour Continuous Run Test
Presentation of a Paper at the 5th Biomass Congress of the Americas	Presentation of a Paper at the 5th Biomass Congress of the Americas
	Firing, Cumulatively, for at least 400 hours and at least 1600 ton of biomass