

USDOE/EPRI BIOMASS COFIRING COOPERATIVE AGREEMENT

Quarterly Technical Report

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ABSTRACT

During the period of January 1, 1999 through March 31, 1999, construction was performed in support of two major demonstrations. Major progress was made on several projects including cofiring at Seward (GPU Genco), and Bailly (NIPSCO). Most of the work was focused on construction and system commissioning activities at the Seward and Bailly Generating Stations. Additionally, petroleum coke cofiring testing was completed at the Bailly Generating Station.

This report summarizes the activities during the first calendar quarter in 1999—the fourth contract quarter in 1998—of the USDOE/EPRI Biomass Cofiring Cooperative Agreement. It focuses upon reporting the results of construction activities and related events.

TABLE OF CONTENTS

<u>CONTENTS</u>	<u>Page #</u>
ABSTRACT	i
TABLE OF CONTENTS	i
TABLES	ii
FIGURES	ii
EXECUTIVE SUMMARY	iii
INTRODUCTION	1
TECHNICAL PROGRESS	9
Project 1 – Combustion Testing at the Seward Generating Station.....	9
Project 2 – Fuel Preparation Tests at Greenidge Generating Station.....	12
Project 3 – Precommercial Testing and Gasification Investigation at TVA	
Fossil Plants	12
Project 4 – Switchgrass Testing at Blount St. Station of Madison Gas & Electric	12
Project 5 – High Percentage Cofiring with Southern Company	12
Project 6 – Cofiring Testing at Michigan City Generating Station of NIPSCO, and	
Demonstration of Cofiring at that Utility	12
Project 7 – Testing Cofiring of Switchgrass by Nebraska Public Power	
District/Sandia.....	17
Project 8 – Waste Plastics Cofiring at Duke Power.....	18
Project 9 – Plastics/Fiber/Pulp Waste Cofiring with SCE&G.....	18
Project 10 – Urban Wood Waste Cofiring in Pittsburgh, PA	18
Project 11 – Toxic Emissions from Cofiring Evaluation	18
Project 12 – Fuel/Powerplant Model Development.....	18
Project 13 – CO ₂ Utilization in Algal Systems.....	18
Project 14 – Combustion Tests and Combustor Development.....	18
Project 15 – Support for Ash Sales from Cofiring Plants	18
Project 16 – CO ₂ Capture and Disposal Options	18

TABLES	Page #
Table 1 . Capital Cost for Seward Generating Station Demonstration	9
Table 2. Capital Cost of the Bailly Generating Station Opportunity Fuel System	14

FIGURES	Page #
Figure 1. Overview of Seward Cofiring System.....	10
Figure 2. Seward System Showing Locations for the new Truck Unloading and Grinding Equipment. The Truck Unloader will be in the Current Truck Discharge Bay (right) and the Grinder will be at the Trommel Discharge (left).	11
Figure 3. Pole Barn at the Bailly Generating Station.....	13
Figure 4. Overview of Opportunity Fuel Reclaim System and Associated Conveyor	13
Figure 5. Close-up of Opportunity Fuel Reclaim System	14
Figure 6. The Influence of Petroleum Coke Cofiring on NOX Emissions	17

EXECUTIVE SUMMARY

The Tenth Quarter of the USDOE-EPRI contract, January 1, 1999 through March 31, 1999, was characterized by engineering and construction activities at the Seward cofiring demonstration of GPU Genco and the Bailly Unit #7 demonstration of NIPSCO.

Technical work that proceeded during the ninth quarter of the contract included the following:

- Construction of the Seward Demonstration projects was completed. This included erection of the pole barn and the Harvistore fuel silo. It included installation of the fuel receiving hopper, the trommel screen, the weigh belt feeder, the blowers and rotary air locks, and all associated piping and controls. All electrical work was completed, and all controls were installed. The system was checked out and made ready for testing in boiler #12. The installed cost of this system was \$987,739.14.
- Completion of construction at the Bailly Demonstration project, with activities including erection of the pole barn, installation of the trommel screen, installation of the Stamler above ground reclaim system, installation of the Hendrik air-slide conveyor, and installation of all associated controls. The system was checked out and made ready for cofiring and trifiring testing.
- Completion of the petroleum coke portion of the test program at Bailly Generating Station.

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 practice of cofiring biofuels with coal, or blending biofuels with other opportunity fuels to be used in coal-fired generating stations, has reached a new stage in its commercialization process. Demonstrations are underway for cofiring with separate wood feeding at a wall-fired boiler—the Seward Generating Station of GPU Genco. Demonstrations also are underway for cofiring biomass with petroleum coke in a cyclone boiler—the Bailly Station #7 boiler of NIPSCO. More utilities are expressing interest in cofiring such as Central & Southwest. Still others are beginning the process of investigating this technology.

Cofiring is generally recognized as the least cost form of “green power” available to utilities which have access to a wood products industry, a furniture industry, a home construction industry, and/or the “urban forest” of broken pallets, tree trimmings, and the like. Cofiring is also considered to be a major contributor to fossil CO₂ reductions. Calculations by Sandia National Laboratories indicate that 10 percent cofiring (heat input basis) could supply one third of the required fossil CO₂ reductions under the proposed Kyoto agreement.

USDOE and EPRI developed a cooperative agreement to support the commercialization of this family of technologies. Some 16 projects have been developed as part of this program, as summarized below. As noted in the Executive Summary, several of these tasks have been completed or cancelled.

1. Combustion Tests at GPU’s Seward Plant (30 MWe, PC)

EPRI and GPU (an EPRI member utility operating the Seward power plant near the Johnstown, Pennsylvania headquarters of GPU’s Penelec system)

will arrange for other cofunding to augment USDOE's cofunding and will conduct a test of mid-level cofiring in a wall-fired PC unit using separate feed for the wood (i.e., not fed through the pulverizers along with the coal, as was done in the recent test cosponsored by USDOE, EPRI, GPU and the State of Pennsylvania at Penelec's Shawville plant in November 1995). This program also includes a long-term demonstration of cofiring at the Seward Generating Station, as a logical extension of the parametric performance testing.

2. Fuel Preparation Tests at NYSEG's Greenidge Plant (100 MWe, PC)

EPRI is cosponsoring New York State Electric and Gas Company (NYSEG) in a test program that focuses on the preparation of wood fuel for cofiring in a tangentially fired PC unit with separate feed for the prepared wood fuel. Size reduction equipment, such as wood "grinders" or hammermills, and drying equipment will be evaluated, and the suitability of the prepared product tested in full-scale combustion in the 100 MWe boiler at NYSEG's Greenidge plant. Mid-level, i.e., about 10% by heat, cofiring is planned.

3. Pre-commercial Test Runs at TVA (~200 MWe)

EPRI is cosponsoring the next testing program at TVA, this one being the long-term "pre-commercial" test runs to cofire wood at levels up to 10% by heat, starting at the cyclone plant (Allen) in Memphis, and continuing at one of TVA's pulverized coal plants. This program includes considering gasification as a basis for cofiring, using the producer gas from biomass as additional fuel injected in the primary furnace.

4. Switchgrass Cofiring with Madison Gas & Electric (50 MWe)

EPRI is cofunding the University of Wisconsin at Madison in a test program being conducted by the University and the local utility (Madison Gas and Electric) at MG&E's Blount Street Station, where an existing retrofit to burn refuse-derived fuel (formerly) and shedded paper waste (currently) in a wall-fired PC unit is to be used to conduct the first U.S. test of cofiring switchgrass along with coal in a full-size utility boiler.

This task has been completed.

5. High-level Cofiring with Southern Company (50 MWe)

Southern Company Services has discussed with EPRI a potential cosponsored project to do long-term testing of high-level (i.e., up to 40% by heat) cofiring of wood with coal, perhaps with some natural gas overfire, in a tangentially-fired PC boiler in Savannah, Georgia. This project would be a follow-up to an initial set of short test runs there in 1993, which indicated that separate feed of this much wood was possible. This test will provide the opportunity to explore the upper limits of cofiring wood with coal in an existing PC boiler. This project also includes demonstration and testing of the entire fuel cycle for switchgrass as a biofuel. It includes growing and harvesting the switchgrass, milling this biofuel, and then cofiring it with coal in both the Southern Research Institute test combustor and then the 60 MW_e Gadsden Station of Alabama Power.

6. Study and Testing with NIPSCO (~500 MWe, Cyclone)

EPRI is completing a study, cofunded by EPRI and Northern Indiana Public Service Company (NIPSCO), to evaluate the fuel supply and the power plant operations for cofiring wood in a full-size cyclone boiler as one of NIPSCO's voluntary measures to reduce emissions of fossil CO₂ under the Climate Challenge program of the federal government. The next phase, assuming the expected favorable findings that cofiring is a low-cost CO₂ mitigation measure, is to be a cofunded test at, perhaps, NIPSCO's Michigan City plant, where manufacturing process waste wood is the expected source of relatively dry wood already at small size and with potential for a 5% by heat cofiring operation in an urban area outside of the normal wood products regions of the South, Upper Midwest or Pacific Northwest. This program also includes demonstrating the results of cofiring testing, over a longer term, at Bailly #7, another NIPSCO cyclone boiler.

7. Switchgrass Test with Nebraska Public Power District

One of EPRI's members, the Nebraska Public Power District (NPPD), has expressed interest in a preliminary evaluation of switchgrass cofiring, an evaluation that can be performed without commitment to a full-size unit

test. EPRI has suggested to NPPD an evaluation based on laboratory testing at the Sandia National Laboratory's Combustion Research Facility in Livermore, California. With USDOE cofunding this would test the ability of the well-controlled, well-monitored test facility at Sandia to provide data and analysis capable of predicting the potential for the fouling of superheater tubes by the cofiring of high-alkali biomass, namely switchgrass, with coal. Combined with (1) the Madison test (Item 4, above), in which NPPD will participate, and (2) the series of tests done by Sandia on both biomass fuels and coals for DOE, NREL, USDOE, EPRI and industry during the past three years, and (3) USDOE's in-house testing of switchgrass/coal cofiring at CERF, this new project is expected to reveal the potential and the limits of laboratory testing as a facilitator of decisions on biomass cofiring.

This task has been cancelled.

8. Waste Plastics Cofiring with Duke (50-200 MWe, PC)

EPRI, Duke Power Company (Duke), and the National Plastics Council have cosponsored a laboratory test and engineering analysis of the cofiring of clean plastic manufacturing wastes with coal in a PC boiler. The next step is a unit test at full-size in a PC boiler, perhaps at 50 MWe or perhaps up in the 200 MWe range, approximate size. While actual biomass cofiring, i.e., waste wood cofiring, may or may not be part of the first unit tests, this project is important for the future of biomass cofiring because it involves a major investor-owned, coal-firing utility, located in a region of a major wood-products industry as well as major, and changing, agricultural and meat/poultry industries, as well as textile industries. It is an excellent test of waste cofiring justified on purely business grounds (fuel savings and customer service) but with potential to move toward environmental grounds, if warranted.

This task has been completed.

9. Plastic/Fiber/Pulp Wastes with SCE&G (~100 MWe, PC)

EPRI has discussed possible follow-on testing with South Carolina Electric and Gas Company (SCE&G), tests that would be a follow-on to a test run in 1993 where mixed plastic and wood fiber were fired with coal

to determine technical feasibility for disposal of an industrial customer's manufacturing residues. Other residues, consisting primarily, or entirely, of pulp wastes rather than plastic may be tested next. Or, a second test, longer and with more variations, using the same plastic/ fiber residue may be the prime focus. The rationale for this as a biomass cofiring test is similar to that for Duke (a neighboring utility in the same wood industry region), but the scope is more directly on biomass, as well as plastic, as fuel, and the options for boiler retrofit may be different.

This task has been cancelled.

10. Urban Wood-Waste Study and Test in Pittsburgh

USDOE has suggested that EPRI join an evaluation of the urban wood waste resource in the industrial/commercial/residential region of Pittsburgh and environs. Coarse, low-cost or no-cost wood wastes would be fired with coal in a stoker boiler at the Bellefield Boiler Plant owned by a consortium that includes the University of Pittsburgh. The University would oversee and monitor a long-term test of low-level (about 2% by heat) cofiring of urban wood wastes (including tree trimmings) together with coal. The key elements of the test would be off-site wood processing, assessment of the urban wood supply and cost by means of actual fuel procurement, and, perhaps, assessment of fines separation and separate cofiring of fines in a normal utility boiler (i.e., PC or cyclone).

This task has been completed.

11. Toxic Emissions

Both EPRI and USDOE have measured trace emissions and effluents from the combustion of coal and from ash resulting from coal combustion. In this new project, EPRI and USDOE will combine their respective data sources, test facilities and expertise in an effort to determine the extent of trace emissions or effluents from the cofiring of wood or other biomass wastes with coal. After an evaluation of data on fuels and control processes, including data on fuel chemistry, ash chemistry, emissions, emission control systems, liquid waste streams and solid waste streams, EPRI and USDOE will plan and conduct a test to measure and/or predict the emissions, if any, of toxic species that may arise from cofiring bio-

mass with coal. This project will explicitly consider a test at the ECTC (Environmental Control Test Center) at the Kintigh power station operated by NYSEG near Buffalo, New York. The best site and fuel combination for a test will be identified and a test will be conducted, if the evaluation indicates that a useful measurement of toxic emissions can be obtained.

This task has been cancelled.

12. Fuel/Powerplant Models, Analysis and Interpretation

In order to interpret results from this entire set of projects and to facilitate the transfer of the results to the industry, EPRI will develop a SOAPP (“State-of-the-Art Power Plant”) module for evaluating wood cofiring situations. SOAPP already has modules for combustion turbine power systems, and SOAPP modules for conventional utility PC and cyclone plants, and also FBC and coal gasification systems, are under development. By July 1996, the first SOAPP cofiring module will be completed, for natural gas as the cofired fuel in a reburn or other mode. This new project (No. 12 of the USDOE/EPRI cofiring program) will add wood cofiring to SOAPP, and also will add a fuels database capable of putting the properties of each new cofiring fuel into a context for comparison to some 50 other fuels and for prediction of slagging/fouling/agglomeration potential in comparison to those other fuels. The result will be a model that will make possible the interpretation of test results from all the cofiring experiments in terms of the performance and cost impacts on a state-of-the-art coal-fired powerplant. Currently, but separate from this proposal, EPRI and USDOE are cooperating on the EPRI-developed CQIM computer model by doing tests to obtain data on slagging/fouling for blends of coals. This work will be used and expanded under this USDOE/EPRI biomass cofiring project. EPRI’s fuels database for biomass and other alternative fuel properties (including slagging indices, etc.) will be incorporated into CQIM, SOAPP and other analytical frameworks as appropriate. EPRI’s biomass resource assessments and tools for developing supply/cost curves will be applied as appropriate to address regional or local biomass resource issues important to USDOE.

13. CO₂ Utilization in Algal Systems for Wastewater Treatment

EPRI and USDOE have independently done experiments and studies of systems that can take advantage of the high rates of capture of CO₂ by aquatic biological systems such as seaweed (kelp), microalgae (ocean and land-based) and halophyte species (both in water and on dry land). This new project under this USDOE/EPRI cofiring project will assess what appears to be one of the few near-term options for an algae-based system to contribute to reductions of CO₂ emissions: the use of CO₂ to speed the growth of algae in water treatment facilities. This approach adds a coproduct value, namely the improved performance of the water (i.e., sewage) treatment plant, that may make the system one of the low cost options for near-term CO₂ mitigation. Two forms of fossil CO₂ reduction are involved: (1) capture of CO₂ into a biomass form, i.e., a process similar to carbon sequestration in forest biomass, but in this case coupled directly to use of a CO₂-enhanced stream like powerplant fluegas; and (2) replacement of a fossil fuel by a biomass fuel, as the algae grown with the enhanced CO₂ stream replace fossil fuel, i.e., a process similar to the CO₂ recycling inherent in all uses of biomass fuels replacing fossil fuels.

This task has been completed.

14. Combustion Tests and Combustor Development

EPRI and TVA have sponsored an initial assessment of slagging combustion as a way to use high-alkali biomass as fuel in power generation without having to solve the problems associated with gas cleanup to meet the purity required by the gas turbines in biomass gasification combined cycle power systems. USDOE has completed the first in a planned series of bench-scale tests of the cofiring of high-alkali fuels with coal in CERF (Combustion Environment Research Facility) at USDOE. This new project in the USDOE/EPRI cofiring program will use test systems at USDOE to obtain data to predict performance and guide design for use of high-alkali biomass fuels in mid- to high-level fractions (approximately 20% to even 100% of the heat into a coal-fired power system). The new project will start with follow-up design and fuel/ash studies that apply and interpret relevant work already completed. Tests will be planned and performed as appropriate, in accord with assessments and plans prepared by EPRI and USDOE staff and contractors, and in accord with an implementation plan approved by USDOE.

This task has been cancelled.

15. Ash Sales

An immediate barrier to the cofiring of biomass with coal in existing coal-fired powerplants is the potential that the flyash from the cofired operation of the plant will not be purchased by the cement industry, which is now the best market for flyash from coal-fired utility boilers. This project will develop and communicate an action plan that will enable a cement industry standards board to make as early as possible a finding that cofired ash is acceptable for purchase from utility powerplants.

This task has been cancelled.

16. CO₂ Capture and Disposal

This project will conduct a series of feasibility studies of various proposed options for capture and disposal of carbon dioxide from U.S. coal-fired power plants. Consideration will be given to both land and ocean-based disposal options in an effort to determine which options would be most amenable to fossil carbon sequestration for both existing and future U.S. power generation capacity. This effort will build on the results of studies previously performed by the International Energy Agency (IEA) Green-house Gas Research and Development Program with joint DOE and EPRI funding.

TECHNICAL PROGRESS

Project 1 – Combustion Testing at the Seward Generating Station

Construction was completed at the Seward Generating Station. This included the truck unloading bin with doffing rolls, a screw conveyor from the truck unloading bin to the trommel screen, the trommel, a pneumatic transport system conveying the screened sawdust from the trommel to a storage silo, a Harvistore storage silo with a Laidig unloading system, a paddle conveyor from the silo outfeed to the weigh belt feeder, a weigh belt feeder discharging to a live bottom bin, 3 blowers and 3 rotary air locks (1 for each burner), piping to the boiler front, burner diffusers, and associated controls. The system was completely checked out for operation. The capital cost for this installation was \$987,739.14. A breakdown of this cost is shown in Table 1.

The current design supplies biofuel to 3 of the 6 burners in the front wall of Boiler #12. The sawdust is injected down the unused centerpipe of a conventional pulverized coal burner, and diffused into the coal flame. The top row of 3 burners is used based upon previous calculations and parametric testing.

Table 1 . Capital Cost for Seward Generating Station Demonstration

Cost Category	Cost
Vendor and Equipment Costs	
Powerscreen Trommel	\$119,500
Weigh Belt Feeder Supply	\$32,891
Pneumatic Transport System Supply	\$97,542
Fuel Barn Supply	\$90,000
Fuel Silo Supply	\$175,000
Electrical Design, Supply, and Erection	\$75,000
Control Room S&E Subcontract	\$15,000
Incline Conveyor Supply	\$80,000
Surge Bin Supply	\$15,000
Motor Control Center Supply	\$10,000
Other Vendor Costs	\$132,880
Total Vendor Costs	\$842,813
Foster Wheeler Costs (including profit on services)	\$144,926
Total System Costs	\$987,739

This system, depicted in Figure 1, is capable of firing 2.5 ton/hr of sawdust to boiler #12. At 10×10^6 Btu/ton, the sawdust is capable of delivering 25×10^6 Btu/hr to the boiler. Seward Generating Station boiler #12 is a 32 MW unit that was installed in 1946, and has a net station heat rate of $\sim 14,000$ Btu/kWh. On this basis, the system supports the generation capacity of 1,785 kW of electricity. For this installation, the capital cost is \$553/kW of biomass-supported capacity.



Figure 1. Overview of Seward Cofiring System

A modern generating station would have a NSHR of about 10,000 Btu/kWh. On that basis, the installation would have a capital cost of \$395/kW supported by biofuel. Note, however, that the boiler is very small, and consequently the capital cost is very high. Several items were purchased at a minimum size, regardless of the boiler capacity. Consequently, as noted previously, engineering for modification of this system to cofire in Boiler #15 was initiated. Boiler #15 is a tangentially-fired 147 MWe boiler with a NSHR of $\sim 10,000$ Btu/kWh.

The design for Boiler #15 was largely completed during this quarter. This design includes a modified truck unloading system to increase the surge capacity of truck unloading and to reduce truck unloading time from >1 hr/truck to <20 min/truck. Further, the truck unloading system as modified will have the capacity to receive trailer

dump trucks as well as walking floor vans. This design includes increased capacity blowers and rotary airlocks. It adds a fourth blower and airlock in order to cofire in all four corners of the T-fired boiler. The design includes additional piping, and specially designed cofiring sawdust injectors for the T-fired unit. A wood grinder will be installed at the discharge of the trommel to convert oversized biomass into useful fuel. Figure 2 depicts the locations for the new truck unloading system and the oversized wood grinding equipment.



Figure 2. Seward System Showing Locations for the new Truck Unloading and Grinding Equipment. The Truck Unloader will be in the Current Truck Discharge Bay (right) and the Grinder will be at the Trommel Discharge (left).

The Seward #15 project is sized for 10 ton/hr, or the support of 10 MWe of capacity. Operationally the unit may fire 6 – 8 ton/hr of biofuel. The modified system will increase the capital cost by an estimated \$658,000, bringing the total capital cost to \$1,646,000. This is equivalent to \$165/kW supported by biofuel. Note the dramatic difference in capital cost on a \$/kW basis; this is the consequence of economies of scale between 32 MWe and 147 MWe.

Project 2 – Fuel Preparation Tests at Greenidge Generating Station

No activity occurred during this quarter.

Project 3 – Precommercial Testing and Gasification Investigation at TVA Fossil Plants

TVA continued to evaluate the gasification project, and has formed a team to develop a project specification.

Project 4 – Switchgrass Testing at Blount St. Station of Madison Gas & Electric

This project was completed.

Project 5 – High Percentage Cofiring with Southern Company

No operational activity occurred on this project

Project 6 – Cofiring Testing at Michigan City Generating Station of NIPSCO, and Demonstration of Cofiring at that Utility

Construction and baseline testing at Bailly Generating Station boiler #7 was completed during this quarter. The system, depicted in Figures 3 – 5, includes a pole barn housing a trommel screen, an above-ground reclaim system (Stamler) for metering opportunity fuel into the plant, and a conveyor linking the Stamler to the main coal supply.



Figure 3. Pole Barn at the Bailly Generating Station.



Figure 4. Overview of Opportunity Fuel Reclaim System and Associated Conveyor



Figure 5. Close-up of Opportunity Fuel Reclaim System

The capital cost for the Bailly Generating Station opportunity fuel cofiring system is \$1,185,685. Table 2 provides a cost breakdown for this system.

Table 2. Capital Cost of the Bailly Generating Station Opportunity Fuel System

Cost Category	Cost
Vendor Supplied Equipment	
Trommel Screen	\$117,000
Above Ground Reclaim	\$256,992
Air Slide Conveyor	\$217,740
Design and Installation	
Electrical Design and Installation	\$123,997
Civil/Mechanical Design and Installation	\$203,446
Other Costs	\$266,510
TOTAL	\$1,185,685

The Bailly Generating Station Boiler #7, fed by the opportunity fuel system, is a 160 MW_e (net) cyclone boiler generating 2400 psig/1000°F/1000°F steam. The Bailly site also houses #8 Boiler, a 320 MW_e (net) supercritical cyclone boiler. The gaseous combustion products from these two units are combined after electrostatic precipitators, and ducted to a Pure Air Scrubber for SO₂ capture and removal. The opportunity fuel system has the capability to supply up to 30 percent of the fuel required by that boiler when blending wood waste and petroleum coke, while being operated 2.5 hrs/day. If the system were fed opportunity fuel all day long, it could supply the entire 480 MW_e at the generating station with 30 percent of its fuel requirement. On the basis of Boiler #7, and including both the petroleum coke and wood waste, the capital cost of the Bailly installation is \$25/kW. On the basis of the entire generating station, the capital cost of the Bailly installation is <\$10/kW supported by opportunity fuels.

In practice, biofuel supplies only 10 percent of the mass of fuel—or 5 percent of the heat input—required for operation of the boilers. Given that condition, the capital cost of the Bailly installation is \$148/kW when considering only Boiler #7, and \$49/kW when considering the entire station. Biofuel could supply up to twice that input if it were economically available, using the current opportunity fuel system; and that would drop the capital cost/unit of capacity to a range of \$25/kW - \$75/kW supported by wood waste. However, since the opportunity fuel system handles both the petroleum coke and the biomass, and since it can handle both boilers, the range of \$8/kW - \$25/kW is a more accurate reflection of its capital cost per unit of capacity.

In addition to completing the construction of the Bailly Generating Station Opportunity Fuel system, the petroleum coke cofiring was completed during the first calendar quarter of 1999. Petroleum coke was blended with a mixture of high sulfur coal and low sulfur coal. Petroleum coke supplied up to 25 percent of the mass of these blends (up to about 30 percent of the heat input for these blends). The testing was used to determine the impact of petroleum coke on boiler efficiency and NO_x emissions.

Cofiring testing at Bailly Generating Station Boiler #7 involved varying the fuel blend, the load, and the excess O₂. Sixteen tests were performed. During each test, fuel samples were taken for analysis along with flyash and slag samples. Control room data were obtained, sufficient to calculate heat and material balances about the boiler. Gaseous combustion products were tested at the entrance and exit of the air heater in order to measure excess O₂, CO₂, SO₂, NO_x, and CO. A portable gas analysis instrument manufactured by Testo was used for this purpose.

The objective of the testing was to determine the influence of petroleum coke cofiring on the following parameters:

- Boiler capacity
- Boiler efficiency
- Boiler operability
- Formation of airborne emissions

The petroleum coke, as would be expected did not impact boiler capacity. Further, the cofiring of petroleum coke did not increase CO emissions. It increased SO₂ emissions consistent with the higher concentration of sulfur in this fuel. However the Pure Air Scrubber makes this an unimportant issue.

The impact of petroleum coke on efficiency, from a practical perspective, is best seen in terms of fuel feed rate. Equation [1] depicts that relationship.

$$FF_{tph} = 9.48 + 0.06(L) - 0.32(PC) \quad [1]$$

Where FF_{tph} is fuel feed rate in tons/hr, L is load, measured as main steam flow in 10³ lb/hr, and PC is percent petroleum coke on a mass basis. The coefficient of determination for this equation, r², is 0.98. All terms, and the equation itself, are highly significant.

The impact of petroleum coke cofiring on NO_x emissions can be seen from equations [2] and [3].

$$NOX_{ppmv} = 315.09 - 7.9(PC) + 66.64(EO2) + 0.42(L) \quad [2]$$

And

$$NOX_{lb/MMBtu} = 0.272 - 0.013(PC) + 0.107(EO2) + 0.001(L) \quad [3]$$

Where NOX_{ppmv} is NO_x, measured in parts per million on a dry basis, corrected to 3 percent excess oxygen (dry) in the stack, EO2 is the percent excess oxygen in the flue gas measured on a total basis and reported in the control room, and NOX_{lb/MMBtu} is NO_x measured in lb/10⁶ Btu. These equations have r² values of 0.81.

In all of the above equations, the influence of load appears small. However, note that the typical main steam flow in this boiler is 1.1 – 1.2 million lbs/hr. Consequently the

numerical value used to depict L is typically 1,100 – 1,200. Similarly, the EO2 term appears high, however the range of values measured during the testing was 2.5% O₂ – 3.3% O₂.

The impact of petroleum coke on NOx emissions can be seen from the graph shown as Figure 6.

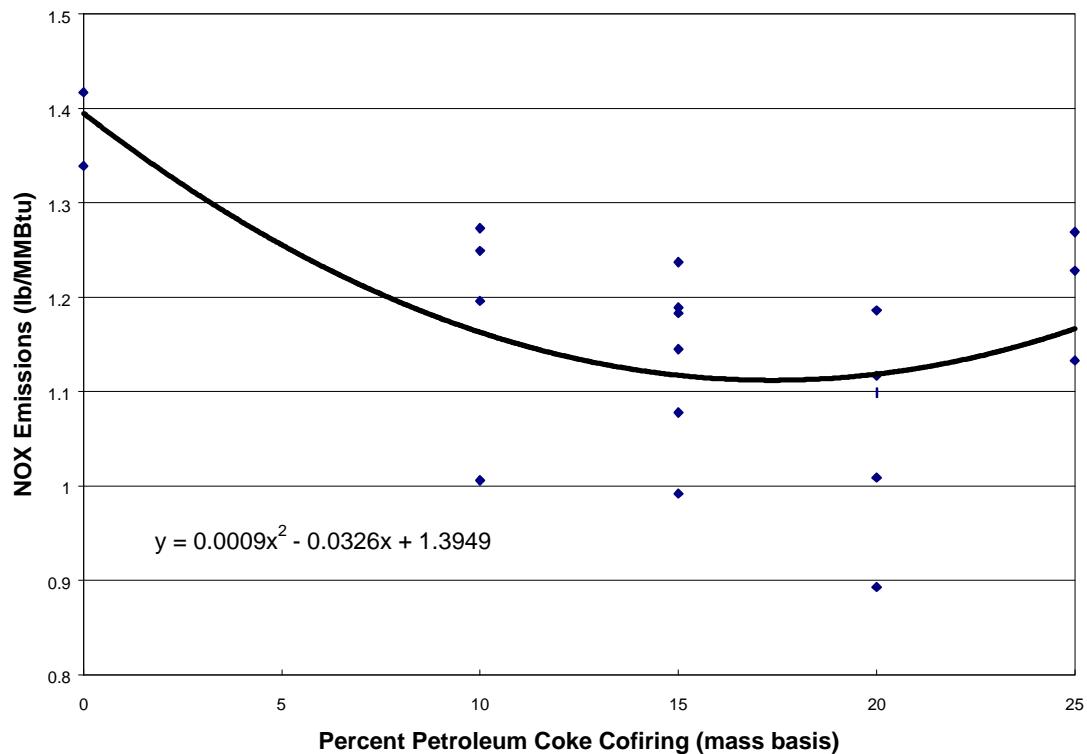


Figure 6. The Influence of Petroleum Coke Cofiring on NO_X Emissions

Note that the optimal percentage for petroleum coke appears to be about 18, on a mass basis, or about 21 percent petroleum coke on a Btu basis.

These petroleum coke cofiring results provide essential inputs to understand the consequences of cofiring biomass with coal alone, and in a blend with petroleum coke.

Project 7 – Testing Cofiring of Switchgrass by Nebraska Public Power District/Sandia

This project was cancelled.

Project 8 – Waste Plastics Cofiring at Duke Power

This project was cancelled.

Project 9 – Plastics/Fiber/Pulp Waste Cofiring with SCE&G

This project was cancelled.

Project 10 – Urban Wood Waste Cofiring in Pittsburgh, PA

This project was completed.

Project 11 – Toxic Emissions from Cofiring Evaluation

This project was cancelled.

Project 12 – Fuel/Powerplant Model Development

No activity occurred this quarter.

Project 13 – CO₂ Utilization in Algal Systems

This project was completed.

Project 14 – Combustion Tests and Combustor Development

This project was cancelled.

Project 15 – Support for Ash Sales from Cofiring Plants

This project was cancelled.

Project 16 – CO₂ Capture and Disposal Options

No activity occurred during this quarter.