

USDOE/EPRI BIOMASS COFIRING COOPERATIVE AGREEMENT

Quarterly Technical Report

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ABSTRACT

During the period of October 1, 1998 through December 31, 1998, significant work was done in direct preparation for several cofiring tests. Major progress was made on several projects including cofiring at Seward (GPU Genco), Allen (TVA), and Bailly (NIPSCO). Most of the work was focused on construction activities at the Seward and Bailly Generating Stations. The conceptual design and feasibility study for gasification-based cofiring at the Allen Fossil Plant was completed. The feasibility study for cofiring at the Pirkey and Northeastern Generating Stations of Central and South West Utilities (C&SW) also was completed.

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

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EXECUTIVE SUMMARY

The Ninth Quarter of the USDOE-EPRI contract, Oct 1, 1998 through Dec 31, 1998, was characterized by engineering and construction activities, plus baseline testing, pursuant to the upcoming demonstrations: the Seward cofiring demonstration of GPU Genco, the Bailly Unit #7 demonstration of NIPSCO, and the proposed gasification demonstration at the Allen Fossil Plant of TVA. Additionally, the ninth quarter was characterized by completion of the feasibility studies for cofiring at the Pirkey and Northeastern Generating Stations of Central & South West Utilities.

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

- construction of the Seward Demonstration projects, with major activities including delivery of the trommel, delivery of the fuel silo, delivery of the fuel delivery systems, delivery of the pole barn, completion of all civil construction activities, completion of all mechanical construction activities except the installation of the final element of the silo, and progress on the electrical installation
- initiation of construction of the Bailly Demonstration project, with activities including receipt of the trommel screen, receipt of the Hendrik conveyor, pouring of major foundations, and erection of structural steel
- completion of the feasibility study final report for gasification-based cofiring at the Allen Fossil Plant
- completion of the feasibility study for cofiring at the Northeastern and Pirkey stations of Central & Southwest Utilities

During this period, a number of other tasks were judged to be completed or cancelled, including:

- Switchgrass Cofiring with Madison Gas & Electric (50 MWe) – Task 4
- Switchgrass Test with Nebraska Public Power District – Task 7
- Waste Plastics Cofiring with Duke (50 – 200 MWe, PC) – Task 8
- Plastic/Fiber/Pulp Wastes with SCE&G (~100 MWe, PC) – Task 9
- Urban Wood-Waste Study and Test in Pittsburgh – Task 10
- Toxic Emissions – Task 11
- CO₂ Utilization in Algal Systems for Wastewater Treatment – Task 13

- Combustion Tests and Combustor Development – Task 14
- Ash Sales – Task 15

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.

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 biomass 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 of the test facility took place during this quarter. The fuel barn was constructed. The trommel screen was received and located in the fuel barn. The fuel receiving system was constructed, and the conveyor installed connecting the fuel receiving system to the trommel screen. The silo was received and was largely completed, along with the transport system from the trommel screen to the silo. The bottom level of the silo remains to be completed. The fuel delivery system has been completed, including the transport system from the silo, the surge bin, the variable speed augers, the lock-hoppers, the blowers, and the piping to the burner front. In the completion of this work, the surge bin, augers, lock-hoppers, and blowers were retained from the previous tests. They were modified and refurbished as required for the demonstration plant service.

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.

The design is being evaluated for modification to supply biofuel to boiler #15. Where boiler #12 is a 32 MWe unit, boiler #15 is a 147 MWe unit. Where boiler #12 is a wall-fired PC, boiler #15 is a tangentially-fired PC. There are four elevations of coal burners in boiler #15. The intent is to use penetrations between the B and C elevations—in the middle of the coal flame. In order to modify the demonstration system to cofire biomass with coal in boiler #15, a fourth lock-hopper and blower must be added, a fourth pneumatic transport pipe must be added, and the system can then capitalize upon the existing investment as well as the existing boiler penetrations. Engineering of this modification commenced during this quarter.

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

The gasification-based cofiring conceptual design and feasibility study was completed for TVA, considering the Allen Fossil Plant as the host site. The Allen Fossil Plant consists of three boilers, each with a capacity of 275 MWe. These are stacked or tower boilers, rather than the more conventional design. Further, these are cyclone-fired boilers that have been recently converted from Illinois basin coal to a blend of western and Powder River Basin (PRB) coals.

The unique configuration of the Allen Fossil Plant boilers, coupled with other factors, helped set the gasifier size at 100 million Btu/hr. This represents about 5 percent of the energy required for a given unit (heat input basis). The gasifier selected was the Primenergy Gasifier, a fixed bed updraft unit with subsequent combustion of the product gas in an external combustor. Larger gasification projects favor the use of fluidized bed gasification technology.

The design basis for this conceptual design was as follows:

Fuel Firing Rate: 100×10^6 Btu/hr biomass to the gasifier

Fuel Feeding Rate: 7.5 - 10 tons biomass/hr @ 5000-6500 Btu/lb biomass

Table 1. Fuel Characteristics for Gasification Analysis

Fuel Characteristics	Average	Minimum	Maximum
Heat Content (Btu/lb)	5000-6500	4000	N/A
Moisture Content (of blended feed)	25	10	50
Ash Content (of blended feed)	5%	N/A	10%

Appropriate Biofuels for Usage

- clean (untreated) wood waste
- woody material grown as energy crops
- herbaceous material grown as energy crops
- non-recyclable paper
- sewage sludge (in small proportions)
- construction, demolition, and land clearing (CDL) materials if clean
- tree trimmings from street maintenance and utility maintenance
- poultry or hog manure
- other special cases including selected industrial wastes
- blends of the above wastes

Design Parameters

- Availability of System: 90%

- Capacity Factor for System: 80%
- Design Life: 20 years
- Project Life: 20 years
- Gas Characteristics
 - >100 Btu/scf chemical energy to combustor (hot combustion products may be supplied to the boiler)
 - Temperature >1000°F
 - Substantially free from particulates (minor concentrations are acceptable)
- Warrantees and Guarantees: 1 year materials and workmanship
- Technology Transferrability:

The implementation of this gasification-based cofiring program is designed such that the gasification approach can be transferred from the Allen Fossil Plant to most utility boilers. The system has inherent flexibility allowing it to expand cofiring from coal-fired boilers to all fossil fuel-fired boilers.

The conceptual design included a materials handling island, a gasifier island, a hot gas transport system, and the balance of plant. The materials handling island included a truck dumper, a trommel screen for fuel quality, and a large silo for on-site fuel storage. This was enclosed in a pole barn. The gasifier included a surge hopper, the gasifier vessel, the external combustion system, and the associated fans. Hot gas ducts were designed to connect the gasifier to the #1 Allen Fossil Plant boiler. Balance of Plant issues included integrating control systems, plant utilities (water, plant air, etc.), ash management, and related concerns. The cost estimate for this installation is as follows:

Table 2. Capital Cost Estimate for Gasification System.

Cost Element	Cost (\$K)
Materials Handling	\$1,865
Gasifier	\$1,874
Hot Gas Duct with 3 supports and 10 expansion joints	\$375
Ash Management System	\$50
Instrumentation and Controls (allowance)	\$25
Burner Modifications	\$280
Site Facilities	not included in estimate
Engineering	included by area
Overheads @ 5%	\$223
Contingencies @ 10%	\$469
Profit @ 10%	\$469
Total (+/-20%)	\$5,630

The economics of gasification were elucidated in this report, focusing upon the relatively small scale (100×10^6 Btu/hr) unit considered for Allen Fossil Plant. What becomes

apparent from the economic assessment of this technology is the fact that gasification can be nearly self-supporting without benefit of CO₂ mitigation credits or other environmental credits. It becomes very self-supporting when greenhouse gas mitigation is considered.

Alternatively, the gasification process in a cofiring application can be used to generate green power at a modest premium. The key is its ability of gasification to use a wide variety of biofuels as feedstocks, broadening the resource base and making biomass cofiring more universally available.

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 characterized the activities during this quarter. The trommel screen was received on site and placed in its location. Footers for the pole barn were poured, and foundations for the Hendrik conveyor were poured. Structural steel for the Hendrik conveyor was erected, along with the platform connecting the Hendrik to the main conveyor.

Baseline testing was conducted and the results were analyzed. These tests used a blend of Illinois basin and Shoshone coals; this blend is the base fuel for the cofiring test program. Results included boiler capacity, efficiency, and emissions measurements.

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

Modeling and support studies work focused upon completing the assessment of cofiring at two plants of Central & South West Utilities: Pirkey Generating Station and Northeastern Generating Station, Unit #3.

Foster Wheeler Development Corporation (FWDC) worked with C&SW personnel to select the two plants for consideration. A third plant was introduced as an alternate, should one of the two base case plants have insufficient biofuel resources. Once the plants were selected, FWDC walked down those plants to determine the physical conditions that have to be considered with cofiring.

Given the plants selected, the scope of services was as follows:

- determine the regulatory climate for the plant
- determine the fuel availability for the plant
- determine the applicability of three cofiring options for the plant: 1) low percentage cofiring using combined biofuel/coal feeding through the pulverizers; 2) moderate percentage cofiring injecting the biofuel directly into a PC boiler; and 3) gasification of the biomass as a fuel preparation technique, followed by injection of the hot, unconditioned gas into a PC boiler fired either with subbituminous coal or by lignite
- determine the environmental consequences of cofiring at the two plants, relative to the regulatory climate
- identify any institutional barriers associated with cofiring at the two plants
- determine the economics of cofiring at the two plants

The key questions associated with the cofiring assessment performed for C&SW are to determine the availability of biofuels, the technical feasibility of cofiring biofuels with one or more techniques, and the economics of using biofuels.

The biomass being evaluated includes not only wood waste, but also animal manures and related feedstocks. While short rotation crops are not explicitly analyzed, the potential for these fuels in the near term is discussed.

The technical issues include boiler capacity, efficiency, operability, and emissions. These issues characterize all cofiring applications. The economic issues include capital cost, fuel cost, and the net present value of the project. They also include the impact of cofiring on the cost of electricity as generated.

Plant Selection.

Plant selection was the first issue of concern. The table below presents the characteristics of coal-fired boilers in the C&SW service area.

Table 3. Characteristics of Coal-Fired Generating Stations of C&SW

Characteristic	Northeast	Flint Creek	Pirkey	Welsh	Okla-Union	Coletto Creek
Location (State)	OK	AR	TX	TX	TX	TX
Unit Number	3-4	1	1	1-3	1	1
Capacity (MW)	473 per boiler	558	721	558 per boiler	664	600
Unit Type	T-fired	W-fired	W-fired	W-fired	W-fired	T-fired
Coal Storage	Silos	Bunkers	Silos	Bunkers	Bunkers	Bunkers
Pulverizer Type	Roller (bowl)	Roller (MPS)	Roller (MPS)	Roller (MPS)	Roller (MBF)	Roller (bowl)
No of Mills	5	6	7	6	6	6
Net Station Heat Rate	10210	11060	12030	10975	10335	9860
Coal Type	PRB	PRB	Lignite	PRB	PRB	Sub
Tons coal/hr(*)	270	312	543	330	390	337
10 ⁶ Btu/hr (*)	4862	5495	7820	5795	6873	5937
Main Steam P	3334	2400	2400	2400	2400	2400
Main Steam T	1000	1000	1000	1000	1000	1000
ESP Type	Cold Side	Hot Side	Cold Side	Hot Side	Hot Side	Hot Side
Sale of Ash	Yes	Yes	No	Yes	Yes	Yes
Other Considerations	(1)	(2)	(3)	(4)	(5)	(6)

Data Taken from: Crass, J. (ed). 1994. Power Plant Equipment Directory, First Edition. UDI/McGraw-Hill. Utility Data Institute. Washington, DC.

(*) Values taken at full capacity as calculated from Crass, J. 1994.
Notes for Table 2.1.

1. Northeastern #3 and #4 were equipped with RDF burners in the top row of burners; these have not been used but could easily be adapted to biomass firing.

2. Flint Creek could be fired using the “Seward Technique” of blowing the biofuel down the centerpipe of the wall-fired burners. Flint Creek has fuel and transportation contract issues that make its use more difficult from an institutional perspective
3. Pirkey is a twin of Dolet Hills Power Plant. The primary difference is that it is operated by C&SW, while Dolet Hills is operated by CLECO.
4. Welsh has a take or pay contract on fuel, eliminating its use
5. Oklaunion has other participating owners, making its use more difficult from an institutional perspective, and making the benefits of biomass use distributed among the other owners
6. Coletto Creek has fuel issues of significance

On the basis of these data plus discussions with C&SW personnel, Pirkey is the first choice. Because it is lignite fired, there is less difference in quality between the biofuel and the base coal. This leads to less impact on the boiler efficiency, the volume of fuel being fed to the boiler, the volume of gaseous combustion products formed that must be moved by the induced draft fan, and the potential for no negative impacts on boiler capacity regardless of cofiring method.

Pirkey is a mine-mouth plant, with truck delivery of coal 24 hours/day. The plant typically consumes 13,000 ton/day of lignite. There is ample space in the coal yard, and adjacent to the plant, to support cofiring operations. The coal from the coal yard is transported to silos feeding fuel to each mill. The coal yard also handles 25 trucks/day of limestone used in the wet scrubber.

The boiler is an opposed firing wall-fired PC unit, with 7 elevations and 8 burners/elevation. The plant has 8 mills, with one always out of service for maintenance. The plant can achieve full load (720 MW_e, gross or 675 MW_e, net) with 7 mills in service. The plant is not fuel feeder limited, but is FD and ID fan limited in the summer, and otherwise is turbine limited. Because of the boiler configuration, separate penetrations would be required for direct injection of sawdust or for injection of producer gas.

Pirkey is a well run plant. It typically operates with about 2 percent excess O₂, with air heater exit temperatures of about 315°F, and with minimal air heater inleakage. The plant typically experiences very little unburned carbon in either the flyash or the bottom ash. However, because Pirkey Station burns lignite, it has a net station heat rate of about 12,000 Btu/kWh.

Pirkey, with its cold side electrostatic precipitator, has a pollution control system that is common for managing flyash from wood. Further, Pirkey does not sell its bottom ash. About 20 percent of the flyash is sold to Tatum Industries for bricks, patio blocks, and related products. About 80 percent of the flyash is used to stabilize scrubber sludge.

Pirkey sells less flyash than other C&SW plants. Pirkey is located in Texas, where most of the C&SW coal-fired generating capacity exists. It represents the regulatory environment of that state.

Northeastern #3 and #4 is the second plant chosen. The Northeastern plant, commissioned in 1979-1980, has access to the Tulsa, OK urban wood waste supply. It fires Powder River Basin (PRB) coal rather than lignite. PRB coal is the dominant supply of solid fuel for the C&SW utilities. Northeastern uses cold side ESP's for particulate control. These plants are located in Oklahoma, representing a different regulatory climate.

Northeastern #3 and #4 consume about 12,000 tons of coal (1 train) per day. The plant site is characterized as having a significant amount of open space. Further, the plant could clear out the area near the emergency reclaim for biofuel processing, if necessary. Northeastern has variable speed drives on its reclaim hoppers, which is favorable to cofiring. The fuel yard is a 24 hour operation, with each bunker being fed by a 500 ton silo. The silos must be refilled every 8 hours. A cofiring operation would have to conform to this arrangement. The conveyor belt feeding the silos operates at 800 ton/hr, and cofiring feed rates would have to be consistent with this.

Northeastern #3 and #4 are tangentially-fired (T-fired) PC boilers, supported by roller mills. A given unit typically fires 270 ton/hr of PRB coal. The units operate with about 4.5 percent excess O₂, an air heater exit temperature of about 280°F, and minimal air heater inleakage. The units are well operated, achieving lower than required NO_x emissions and opacity emissions. The net station heat rate for this plant is about 10,300 Btu/kWh, which is among the lowest of the coal-fired generating stations in the C&SW system.

The dominant feature of Northeastern, setting it apart from other C&SW plants, is the presence of waste fuel firing ports in each boiler. These ports were designed to give C&SW the opportunity to cofire RDF, if produced by the city of Tulsa. These firing ports are located above the top elevation of coal burners, creating a 6th firing elevation if used. These refuse injection points significantly reduce the complexity of the cofiring system if separate injection or gasification is employed.

Regulatory Climate

The regulatory climate for both sites was determined to be favorable.

Fuel Supply

The initial interest focused upon poultry litter, a material commonly available in eastern Oklahoma and Texas. Numerous problems were identified including:

- Seasonality of fuel supply
- Value of poultry litter to farmers
- High ash/high alkalinity of ash in poultry litter
- High chlorine content of litter

For these and related reasons, poultry litter was abandoned as a potential biofuel. The focus shifted to wood waste from primary and secondary sources; and the potential for post-industrial use of some wood products.

Sufficient quantities of wood waste are available to warrant further consideration to biomass fuels. The total available as shown in the table below, is 857,000 tons/year. Some 46 plants or generating units are located within 75 miles of the Pirkey.

Table 4. Available Wood Waste Residue in the Pirkey Generating Station Area

Wood Type	Bark	Chippable	Fines/ Shavings	Sawdust	Bark/ Sawdust	Bark/ Sawdust/ Chips Mix	Chipped Logs	Used Pallets	Used RR Ties
Green	210,354	39,320	8,633	249,501	130,000	5,200	10,400		
Dry		1,968	9,750	40,460				11,900	100,000
Kiln-Dried		2,245	10,400	6,360	20,280				
TOTAL	210,354	43,533	28,783	296,321	150,280	5,200	10,400	11,900	100,000

Typical prices at the point of generation range from \$0.00/ton to \$5.00/ton with the average price being about \$2.00/ton. The typical trucking rate in the area is \$0.08 to \$0.09 per loaded ton-mile for green wood waste. Assuming an average haul distance of 50 miles, this results in a cost of \$6.00 - \$6.50/ton, or \$0.64 - \$0.70/10⁶ Btu. Costs could reach \$1.00/10⁶ Btu if the wood waste is \$5.00/ton and the transportation cost is \$0.09/loaded ton-mile.

There is significantly less wood available in the Northeastern area, and the costs are somewhat higher. Approximately 130,000 tons of wood waste was identified within 75 miles of Northeastern Generating Station. This does not include dunnage from the Port of Catoosa, construction and demolition materials, and other potential sources of biofuel. The figures below present the incremental cost and weighted average cost of these fuels.

Figure 1. Depicting Incremental Cost Curve for Biofuel at Northeastern Station

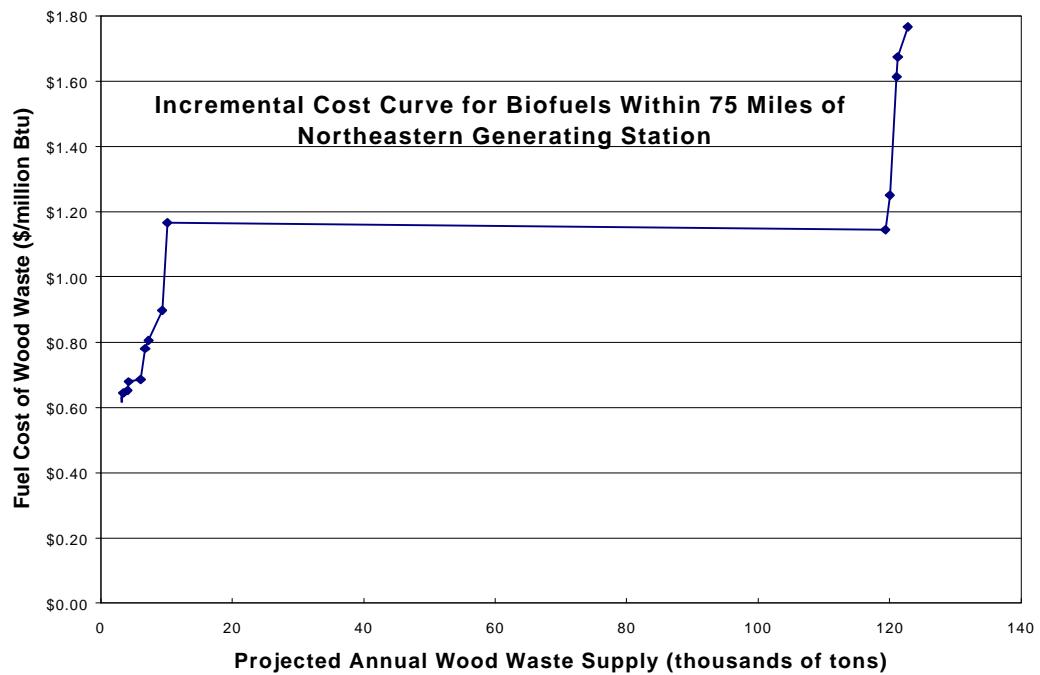
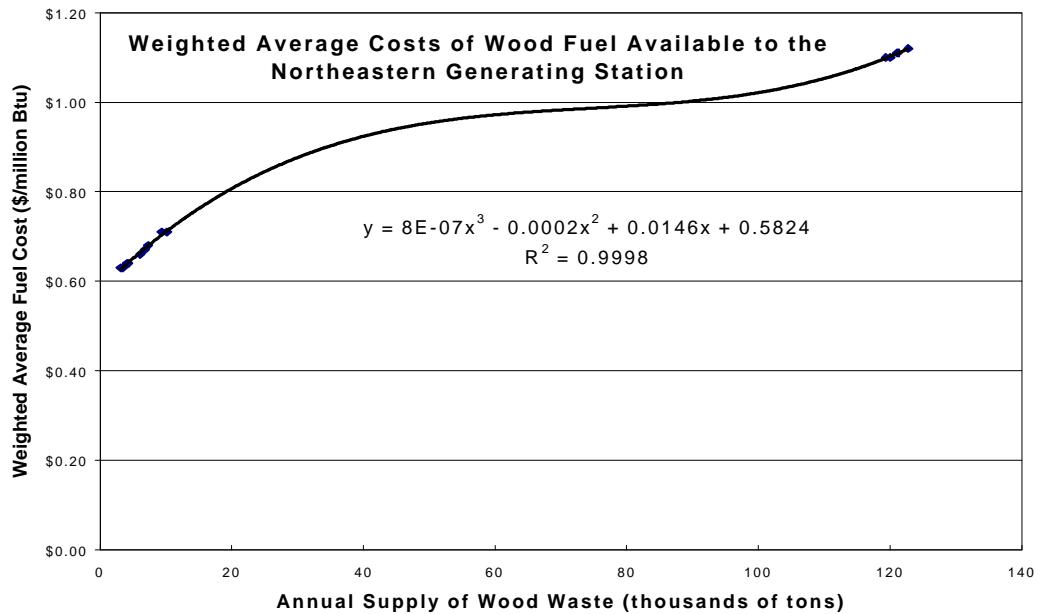


Figure 2. Depicting Weighted Average Cost Curve for Biofuel at Northeastern



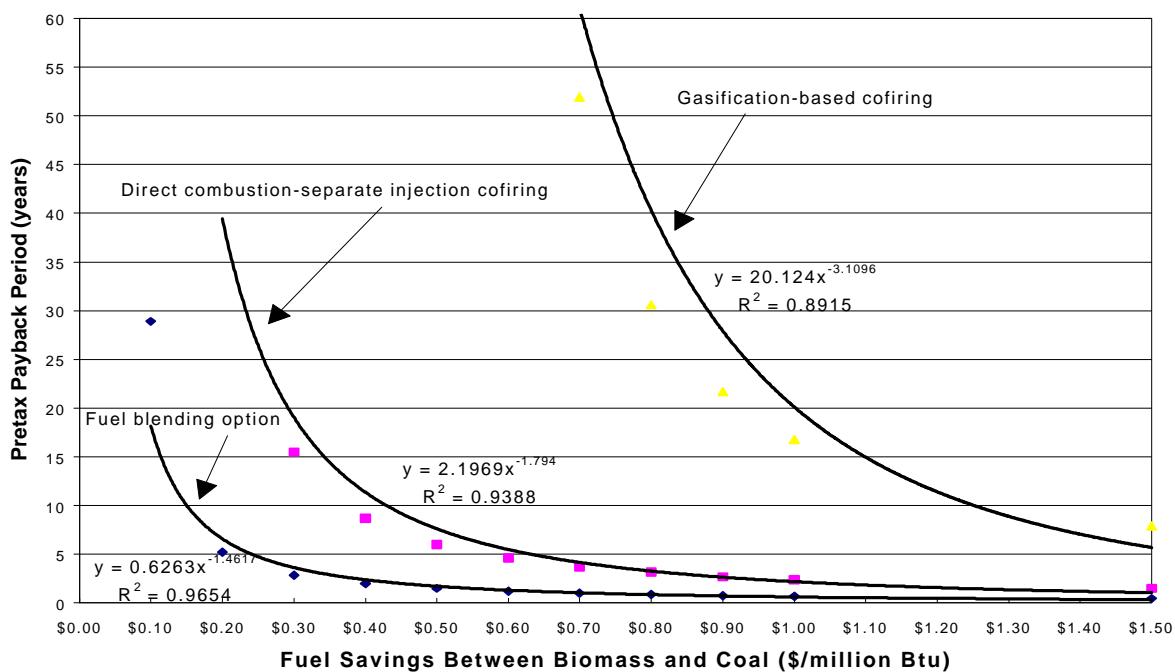
The fuel supply and cost issue confirmed that Pirkey is the preferred site.

Cofiring Concepts for Both Stations

Engineering concepts were developed for both the Pirkey and Northeastern stations, and these concepts included blending of biofuel with coal in the fuel yard, direct combustion of biomass with separate injection of the biofuel apart from the coal handling system, and gasification-based cofiring.

The economics favor blending of biofuel with coal in the fuel yard for both Pirkey and Northeastern. The capital costs determine the economics. For the fuel blending option, the capital cost is ~\$1 million. For direct combustion with separate injection, the capital cost is ~\$3 million. For gasification-based cofiring, the capital cost is \$11.2 million. The economics currently are based upon fuel savings—and the fuel price differential between coal or lignite and biomass. These economics are shown in the Figure below.

Figure 3. Pretax Payback Periods for Three Cofiring Options at the Pirkey Station



The economics for Northeastern are less favorable than the economics for Pirkey Station.

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.