Report Title:	Quarterly Report for the Conceptual Design Assessment for the Co-Firing of Bio-Refinery Supplied Lignin Project
Type of Report:	Quarterly Report, First Quarter of 2001
Reporting Period Start Date:	January 1, 2001
Reporting Period End Date:	March 31, 2001
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Date Report Was Issued:	April 2001
DOE Award No.:	DE-FC26-99FT40670
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ABSTRACT

The major aspects of this project are proceeding toward completion. Prior to this quarter, design criteria, tentative site selection, facility layout, and preliminary facility cost estimates have been completed and issued for review. Processing of bio-solids was completed, providing material for the pilot operations. Pilot facility design, equipment selection, and modification were completed during the fourth quarter of 2000. Initial pilot facility shakedown was completed during the fourth quarter.

After some unavoidable delays, a suitable representative supply of municipal solid waste (MSW) feed material was procured. During this quarter (first quarter of 2001), shredding of the feed material was completed and final feed conditioning was completed. Pilot facility hydrolysis production was completed to produce lignin for co-fire testing. Pilot facility modifications continued to improve facility operations and performance during the first quarter of 2001. Samples of the co-fire fuel material were sent to the co-fire facility for evaluation.

The TVA-Colbert facility has neared completion of the task to evaluate the co-location of the Masada facility on the operation of the power generation facility. The TVA-Colbert fossil plant is fully capable of providing a reliable steam supply. The preferred steam supply connection points and steam pipeline routing have been identified. The environmental review of the pipeline routing has been completed and no major impacts have been identified. Detailed assessment of steam export impacts on the Colbert boiler system have been completed and a cost estimate for steam supply system is being developed.

REPORT NO. 00-10734/04

QUARTERLY REPORT FOR THE CONCEPTUAL DESIGN ASSESSMENT FOR THE CO-FIRING OF BIOREFINERY SUPPLIED LIGNIN PROJECT

PROJECT NO. 00-10734
MASADA DOE LIGNIN STUDY

MASADA RESOURCE GROUP, LLC
BIRMINGHAM, AL

DATE: APRIL 30, 2001

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DATE: APRIL 19, 2001

1. INTRODUCTION

The development of renewable domestic fuel sources is a desirable goal with positive economic and environmental impacts. Masada Resource Group (MRG) has developed a proprietary process for the conversion of municipal solid waste (MSW) and sewage sludge (SS) into ethanol (CES OxyNol™ Process). One of the byproducts of this process is a solid lignin product. MRG has developed a method for using this MSW-derived lignin as a solid fuel for steam generation. In this joint research project, a conceptual design will be developed that joins a CES OxyNol™ facility with a Tennessee Valley Authority (TVA) coal-fired power plant (the TVA-Colbert facility).

MRG is working with Harris Group Inc. (HGI), TVA, and the Department of Energy (DOE) to develop a conceptual design for the co-firing of bio-refinery-derived lignin fuel in a coal-fired steam boiler. This project will research the de-watering and fuel properties of the CES OxyNol™-derived fuel. The project will evaluate the technological feasibility and cost/benefit analysis of co-locating a CES OxyNol™ facility with the TVA-Colbert facility. In this configuration the bio-refinery supplies boiler fuel (lignin) to the Colbert facility and the Colbert facility provides the process steam needed for the CES OxyNol™ process. The co-location has the benefit of providing a low-cost renewable biomass fuel source that can be co-fired with coal. Co-location also reduces the capital and operating costs of the CES OxyNol™ process and provides environmental gains by reducing the impact of coal combustion and providing an environmentally acceptable method for the disposal of solid waste.

This project has been divided into six separate but related tasks to reach the aforementioned goals of the project. Progress has been made on most of the specific tasks. The goal of the pilot run is both to evaluate dewatering options and to generate lignin to be used in the co-fire evaluation at the National Energy Technology Laboratory (NETL) or an alternate facility. Pilot facility modification, shake-down. and lignin production were completed.

The first task is the overall feasibility analysis for the co-location of the Masada facility with a TVA power facility. Task 1

- Identified facility design criteria
- Identified potential facility locations and preliminary site layout
- Evaluated the economic impact associated with co-location

The second task is the assessment of the impacts on the TVA facility. TVA's Fossil Engineering Organization is performing a preliminary engineering assessment for delivering steam from the TVA-Colbert fossil plant to the proposed Masada waste processing facility. The study will identify

- Steam supply connection point in the Colbert plant steam cycle
- Steam pipe routing from the steam cycle connection to the Colbert plant boundary
- Capacity and heat rate impacts on the Colbert plant resulting from the steam supply
- Environmental review of the steam pipe installation
- Capital cost of the steam supply design, materials, and installation
- Operation and maintenance cost impacts on the Colbert plant resulting from the steam supply

This information will be used to develop a price for the steam to be supplied from the Colbert plant to the Masada facility.

Tasks 3 and 4 involved the pilot plant facility design, modification, and shakedown for the production of lignin. Pilot plant design and modification have been completed. The pilot plant production operation occurred in February. Transitioning from the pilot facility shakedown phase to the operations phase was delayed due to difficulties in obtaining a representative MSW feed material. A representative sample was procured during the fourth quarter of 2000. Feed conditioning, including shredding and drying, was completed this quarter.

Task 5 is the production of lignin in the TVA pilot facility. This activity was largely completed this quarter. Task 6, lignin washing and dewatering, is anticipated to occur next quarter, followed by Task 7, co-fire testing.

2. EXPERIMENTAL

TVA has considerable experience in the acid hydrolysis process and its experimental experience has been and will be applied to the lignin production and washing. The lignin dewatering and conditioning will be studied in conjunction with dewatering equipment vendors and with input from the test burn facility. The hydrolysis process used during these tests to produce lignin samples is the proprietary Masada CES OxyNol^{TM} process.

During the third quarter of 2000, TVA prepared samples of unfiltered processed sewage sludge and hydrolyzate to be shipped to NETL (George Wen) for dewatering tests. Information on TVA's pilot plant safety procedures was also sent to NETL. The project team awaits results of the NETL testing.

Dewatering testing and hydrolysis pilot processing completed during the first quarter of 2001 are part of continuing tests as part of this project. These tests are in progress and final reporting will include nonproprietary experimental descriptions as necessary.

3. RESULTS AND DISCUSSION

3.1 General

Progress on the major tasks of this project continues. Engineering impact of the co-fire concept is favorable. TVA-Colbert completed the evaluation of steam supply options and impacts indicating that supply options exist. A cost estimate for the system modifications and supply is underway. Pilot facility modifications have been completed with further modifications to be undertaken as needed. The pilot plant has successfully completed shakedown operation and lignin production. Some delays had occurred due to difficulty in procuring a suitable representative MSW feed supply. A feed supply was procured and lignin production completed early in the first quarter of 2001. TVA is currently preparing for the lignin washing and dewatering.

NETL has expressed reservations with respect to the co-fire of the lignin/sewage sludge mixed material in the NETL test boiler. The project team is currently investigating other options with the likely outcome that co-fire testing will be completed at an alternate facility. Contact with the alternate facility (EERC) has been initiated and it has indicated that co-firing of this type of material should be easily accomplished. Samples of the lignin and bio-solids co-fire feed materials will be shipped to the co-fire test site for feed characterization.

3.2 Engineering Impact Analysis

During the first quarter of 2001 no significant changes were identified from the previous engineering impact analysis. During the third quarter of 2000 preliminary design criteria for the Masada Colbert facility were issued to the team members and a preliminary site for the Masada facility was selected. Final site selection will be predicated on community approval and economic viability. The design criteria and site identification allow the TVA-Colbert power facility to complete the investigations into the impacts and facility modifications that would be required for this project. TVA power is completing an investigation of the impacts on the power plant operations. Results of the TVA-Colbert study to date are reported below in paragraph 3.8.

3.3 MSW Feed Procurement and Conditioning

As discussed in previous reports, an unavoidable delay in the acquisition of a representative MSW supply caused a delay in pilot plant operations for lignin production and washing. A representative MSW supply was procured and delivered to an equipment vendor testing facility for feed conditioning. A sort of the feed material was required prior to feed conditioning. Sorting was completed during November 2000.

After sorting, the material was shredded using a vendor-supplied rental unit. The rental machine configuration as supplied had incorrect sizing resulting in delays in MSW shedding. The sizing was corrected and the MSW was shredded. A portion of the material was dried in a vendor-supplied test dryer. An alternative style dryer was also tested at TVA. A vendor equipment representative evaluated the operation and recommended dryer changes to improve operations. The pitch of the dryer, dryer rpm, and feed rate of the RDF were all increased, improving dryer performance. All the MSW material was shipped to TVA for processing. Both drying methods proved acceptable for commercial application and feed conditioning was completed by early February.

3.4 Pilot Plant Modifications

For lignin production, TVA's pilot facility was modified for Masada's proprietary process. TVA, Lizan, and Harris worked with Masada to identify equipment needed for the lignin production pilot run. TVA's pilot facility provided much of the equipment that was used. Additional equipment required rental or purchase for this project. This equipment has been procured and was incorporated into the pilot facility. During pilot operations, several valves were replaced with full port valves to improve operations.

3.5 Pilot Facility Hydrolysis Operations

As described previously, TVA's pilot facility was set up to operate the OxyNol™ process in a batch mode. During hydrolysis operations, the pump had some difficulty handling metal materials in the RDF. A new different design impeller was installed, greatly improving the

pump performance. A test was conducted with the new impeller in the pump. Various metal pieces were fed and most were handled easily by the pump.

During February, Batches 8 through 20 were processed. Each batch was approximately 200 lb of RDF. Proprietary amounts of acid and hot sewage sludge supernatant were added to each batch. Double batches were processed in the cook tank and pumped to a filter press for lignin dewatering. The analytical data is being processed and conversions and yields calculated.

The resulting filtered hydrolyzate from the 13 batches was filtered through a modified pool filter, then placed in 55-gallon drums. A total of 16.25 drums were filled with hydrolyzate. This hydrolyzate was set aside for further testing and processing beyond the scope of this project.

The residue from the filter press was loaded into drums. Seven drums of residue were obtained. Moisture analysis of samples from the drums showed that the lignin residue averaged about 55% moisture. A summary of results of the lignin analysis are shown in the following table.

Lignin Residue Dried at 105°C	
Sample	**Solids (%)**
Drum No. 1	48.59
Drum No. 2	53.50
Drum No. 3	46.27
Drum No. 4	49.05
Drum No. 5	46.35
Drum No. 6	45.67
Drum No. 7	51.71

Based on moisture content for samples dried at 45°C (data not shown), analysis of the acid content of the unwashed lignin residue was performed.

Based Samples, Average Solid Content at 45°C			
Sample	**Calc Solids (g)**	**Calc Moisture (g)**	**H_2SO_4/solids (g/g)**
Drum No. 1	6.80	4.80	0.22
Drum No. 2	8.05	2.85	0.29
Drum No. 3	6.34	4.57	0.22
Drum No. 4	6.68	3.91	0.21
Drum No. 5	5.97	5.03	0.18
Drum No. 6	5.67	5.20	0.18
Drum No. 7	6.46	3.86	0.20

This and similar data tables were used to determine the amount of wash water needed for the lignin residue. A small sample of lignin residue (5 gallons) was washed in the lab and will be sent to EERC for combustion evaluation prior to washing of the remaining residue.

During March, the pilot plant was cleaned and the mixer shipped back to the vendor. The drums containing the sewage sludge solids are being stored. This material will also be shipped to the co-fire location for combustion testing after evaluation of the samples is completed.

3.6 Lignin Dewatering Testing

As mentioned in paragraph 3.5, a 5-gallon sample of lignin residue was washed in the laboratory to achieve the design composition for the Masada process. This sample material was shipped to the test burn facility for evaluation. Once final evaluation of this material is completed, TVA will wash and dewater the remaining lignin material in preparation for final co-fire testing.

3.7 Pilot Schedule

The following tentative schedule represents our projected timeline for operation of the TVA pilot facility for the washing and dewatering of the lignin for co-fire testing and shipment of the material to the co-fire testing site. This schedule is subject to change.

Task	Week of
Ship sample of material to co-fire facility for evaluations	April 9
Evaluations and recommendations for washing/drying	April 23
Lignin washing and dewatering	April 30
Shipment of lignin to co-fire test site	May 14
Co-fire testing and fuel evaluation	TBD

3.8 Preliminary Engineering Interface Assessment and Design for TVA Coal-Fired Facility

The Colbert fossil plant consists of five pulverized coal-fired electricity generating units. Units 1 through 4 are identical and have the following characteristics:

- Capacity 200 MW
- Main steam flow 1,287,000 lb/hr
- Main steam pressure 1815 psig
- Main steam temperature 1050°F
- Reheat steam flow 1,122,000 lb/hr
- Reheat steam pressure 402 psig
- Reheat steam temperature 1050°F
- Steam turbine extractions eight at various pressures

Units 1 through 4 began commercial operation in 1955. Unit 5 is a unique, larger capacity (500 MW) unit and was not considered as a steam supply source.

HGI provided TVA the design case steam requirements of the Masada facility. The requirements include the following:

- Steam pressure 150 psig
- Steam quality saturated
- Base demand 217,420 lb/hr
- Peak demand 229,420 lb/hr

The peak demand is the basis for the TVA engineering assessment with 82% of the steam condensate returned to the Colbert system.

A location for the Masada facility has been identified adjacent to the western boundary of the Colbert plant reservation. This location is the basis of steam pipeline routing and steam line pressure drop calculations.

The design of the steam supply system is complete. For reliability reasons, the steam supply arrangement will be configured so that steam will be supplied from one unit or equally divided from two units. Main steam from the steam generators will be the source. The steam conditions required by the Masada facility will be met by attemperation and throttling. The analysis of impacts on the turbine cycle has been completed.

The steam pipe routing has been finalized and the environmental review completed. The selected route had no significant environmental impacts. The selected pipeline route includes 7,345 ft of pipeline with four road crossings and one crossing of Cane Creek.

The cost estimate for the steam supply and steam pipe is underway and nearing completion. The cost estimate and the output and heat rate impacts will be used to determine a price for the exported steam.

4. CONCLUSION

The initial design criteria for the MSW to ethanol facility have been completed along with preliminary site identification and layouts for the processing facility. These items were the first step in evaluating the feasibility of this co-located facility.

The delay of suitable feed material has delayed the lignin production operations. A suitable MSW feed material was delivered and feed conditioning was completed. Hydrolysis operations and lignin production in the TVA facility were completed. Lignin samples were analyzed to estimate the required washing and lignin moisture content. Lignin washing and dewatering were tested on a small laboratory sample and the sample sent to the co-fire facility for fuel evaluation. Once evaluation is completed, the composite fuel mixture will be shipped to the testing facility for co-fire evaluation.

The TVA-Colbert fossil plant is fully capable of providing a reliable steam supply for the proposed Masada waste processing facility. The steam supply connection point in the Colbert plant steam cycle has been identified. The pipeline routing from the Colbert powerhouse to the Colbert plant boundary has been identified. The environmental review of the pipeline routing has been completed and no impacts have been identified. The cost estimate for the steam supply system is underway and this task in the project is nearing completion.

5. LIST OF ACRONYMS AND ABBREVIATIONS

DOE	Department of Energy
HGI	Harris Group Inc.
MRG	Masada Resource Group, LLC
MSW	Municipal Solid Waste
NETL	National Energy Technology Laboratory (also FETC, Federal Energy Technology Center)
PFD	Process Flow Diagram
RDF	Refuse Derived Fuel (also MSW)
SS	Sewage Sludge
TVA	Tennessee Valley Authority
TVA-PPI	TVA Public Power Institute
WWT	Waste Water Treatment