THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

Environmental and Sustainable Technology Evaluation (ESTE)

U.S. Environmental Protection Agency

SOUTHERN RESEARCH INSTITUTE

ESTE Joint Verification Statement

TECHNOLOGY TYPE:	Biomass Co-firing
APPLICATION:	Industrial Boilers
TECHNOLOGY NAME:	Renewafuels Pelletized Wood Fuel
COMPANY:	Renewafuels, LLC
ADDRESS:	13420 Courthouse Boulevard Rosemount, MN 55068

The U.S. Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV program is to further environmental protection by accelerating the acceptance and use of improved and cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the purchase, design, distribution, financing, permitting, and use of environmental technologies. This verification was conducted under the Environmental and Sustainable Technology Evaluation (ESTE) program, a component of ETV that was designed to address agency priorities for technology verification.

The goal of the ESTE program is to further environmental protection by substantially accelerating the acceptance and use of improved and innovative environmental technologies. The ESTE program was developed in response to the belief that there are many viable environmental technologies that are not being used for the lack of credible third-party performance data. With performance data developed under this program, technology buyers, financiers, and permitters in the United States and abroad will be better equipped to make informed decisions regarding environmental technology purchase and use.

This ESTE project involved evaluation of co-firing common woody biomass in industrial, commercial or institutional coal-fired boilers. For this project ERG was the responsible contractor and Southern Research Institute (Southern) performed the work under subcontract. Client offices within the EPA, those with an explicit interest in this project and its results, include: Office of Air and Radiation (OAR), Combined Heat and Power (CHP) Partnership, Office of Air Quality Planning and Standards (OAQPS), Combustion Group, Office of Solid Waste (OSW), Municipal and Industrial Solid Waste Division, and ORD's Sustainable Technology Division. Letters of support have been received from the U.S. Department of Agriculture Forest Service and the Council of Industrial Boiler Owners.

TECHNOLOGY DESCRIPTION

Wood Pellets from a Renewafuel, LLC facility in Michigan were used for this verification. The pellets were a pressed oak product which is made from the waste of trailer bed manufacturing. No glue or adhesives were used in the manufacture of the pellets. Proximate analyses of the pelletized wood used for this testing is as follows:

Component	% by Weight
Moisture	6.6
Ash	0.43
Volatile matter	75.5
Fixed carbon	17.3

The average heating value was 7,688 British thermal units per pound (Btu/lb).

Testing was conducted at the University of Iowa (UI) Main Power Plant's Boiler 10. The UI Main Power Plant is a combined heat and power (CHP) facility which serves the main campus and the UI hospitals and clinics. The plant continuously supplies steam service and cogenerated electric power. There are four operational boilers at the facility, one stoker unit (Boiler 10), one circulating fluidized bed boiler (Boiler 11), and two gas package boilers (Boilers 7 and 8). Boiler 10 was used during this co-firing demonstration. Boiler 10 is a Riley Stoker Corporation unit rated at 170,000 lb/h steam (206 MMBtu/h heat input) at 750 degrees Fahrenheit (°F) and 600 pounds per square inch, gauge (psig). This unit normally operates in pressure control (swing) mode on a multi-boiler header at a typical operating range of 120,000 to 140,000 lb/h steam. The unit can be base loaded up to its rated capacity or swing down to a minimum load of 90,000lb/h. The facility includes a mechanical dust collector and electrostatic precipitator (ESP) to control particulate emissions. Bottom ash and fly ash generated by Boilers 10 and 11 are collected, blended, and shipped to a nearby limestone quarry where it is mixed with water, solidified, and used to build roads or fill.

Forty-four tons (T) of Renewafuel's wood based pellets were delivered to the River Trading site and mixed with stoker coal using a front end loader. The weight of the total mixture was 294 T, for a pellet fraction by weight of approximately 15 %.

VERIFICATION DESCRIPTION

This project was designed to evaluate changes in boiler performance due to co-firing woody biomass with coal. Boiler operational performance with regard to efficiency, emissions, and fly ash characteristics were evaluated while combusting 100 percent coal and then reevaluated while co-firing biomass with coal. The verification also addressed sustainability issues associated with biomass co-firing at this site.

The testing was limited to two operating points on Boiler 10:

- firing coal only at a typical nominal load
- firing a coal:biomass "co-firing" mixture of approximately 85:15 percent by weight at the same operating load

Under each condition, testing was conducted in triplicate with each test run approximately three hours in duration. In addition to the emissions evaluation, this verification addressed changes in fly ash composition. Fly ash can serve as a portland cement production component, structural fill, road materials, soil stabilization, and other beneficial uses. An important property that limits the use of fly ash is carbon content. Presence of metals in the ash, particularly mercury (Hg), can also limit fly ash use, such as in cement manufacturing. Biomass co-firing could impact fly ash composition and properties, so this verification included evaluation of changes in fly ash carbon burnout (loss on ignition), minerals, and metals content.

During testing, the verification parameters listed below were evaluated. This list was developed based on project objectives cited by the client organizations and input from the Biomass Co-firing Stakeholder Group (BCSG).

Verification Parameters:

- Changes in emissions due to biomass co-firing including:
  - Nitrogen oxides (NO_X)
  - Sulfur dioxide (SO_2)
  - Carbon monoxide (CO)
  - Carbon dioxide (CO_2)
  - Total particulates (TPM) (including condensable particulates)
  - Primary metals: arsenic (As), selenium (Se), zinc (Zn), and Hg
  - Secondary metals: barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), manganese (Mn), nickel (Ni), and silver (Ag)
  - Hydrogen chloride (HCl) and hydrogen fluoride (HF)
- Boiler efficiency
- Changes in fly ash characteristics including:
  - Carbon, hydrogen, and nitrogen (CHN), and SiO_2, Al_2O_3, and Fe_2O_3 content
  - Primary metals: As, Se, Zn, and Hg
  - Secondary metals: Ba, Be, Cd, Cr, Cu, Mn, Ni, and Ag
  - fly ash fusion temperature
  - Resource Conservation Recovery Act (RCRA) metals and Toxic Characteristic Leaching Procedure (TCLP).
- Sustainability indicators including CO_2 emissions associated with sourcing and transportation of biomass and ash disposal under baseline (no biomass co-firing) and test case (with biomass co-firing) conditions.

Rationale for the experimental design, determination of verification parameters, detailed testing procedures, test log forms, and QA/QC procedures can be found in Test and Quality Assurance Plan titled *Test and Quality Assurance Plan – Environmental and Sustainable Technology Evaluation Biomass Co-firing in Industrial Boilers.*

Quality Assurance (QA) oversight of the verification testing was provided following specifications in the ETV Quality Management Plan (QMP). Southern's QA Manager conducted an audit of data quality on a representative portion of the data generated during this verification and a review of this report. Data review and validation was conducted at three levels including the field team leader (for data generated by subcontractors), the project manager, and the QA manager. Through these activities, the QA manager has concluded that the data meet the data quality objectives that are specified in the Test and Quality Assurance Plan.

VERIFICATION OF PERFORMANCE

Boiler Efficiency

For the efficiency testing, mass feed of blended coal and wood was increased to attempt to repeat heat input as closely as possible to the baseline coal only tests.

Table S-1. Boiler Efficiency

Test ID	Fuel	Heat Input (MMBtu/hr)	Heat Output (MMBtu/hr)	Efficiency (%)
Baseline 1	100 % Coal	264.6	224.4	84.8
Baseline 2		264.2	223.9	84.8
Baseline 3		264.8	223.7	84.5
Baseline 4		267.6	228.8	85.5
Cofire 1	Blended Fuel (85.1 coal: 14.9 wood)	275.7	229.7	83.3
Cofire 2		271.9	230.0	84.6
Cofire 3		272.5	230.3	84.5
Baseline Average		265.3	225.2	84.9 ±0.4
Cofire Average		273.4	230.0	84.1 +0.7
Absolute Difference		8.1	4.8	-0.7
% Difference		3.0%	2.1%	-0.9%
Statistically Significant Change?		na	na	No

The average efficiencies during baseline (coal only) and co-firing tests were 84.9 ± 0.4 and 84.1 ± 0.7 percent respectively. This change is not statistically significant, so it is concluded that co-firing biomass at the 15 percent blending rate did not impact boiler efficiency performance.

Emissions Performance

Table S-2. Gaseous Pollutant Emissions (lb/MMBtu)

Test ID	Fuel	SO_2	CO_2	NO_x	CO
Baseline 1	100 % Coal	2.49	207	0.473	0.081
Baseline 2		2.28	206	0.442	0.083
Baseline 3		2.48	206	0.438	0.085
Baseline 4		2.63	202	0.486	0.102
Cofire 1	Blended Fuel (85.1 coal: 14.9 wood)	2.12	207	0.487	0.089
Cofire 2		2.11	207	0.525	0.081
Cofire 3		2.26	207	0.506	0.081
Baseline Averages		2.47 ± 0.14	205 ± 2	0.460 ± 0.02	0.088 ± 0.010
Cofire Averages		2.16 ± 0.08	207 ± 0.3	0.506 ± 0.018	0.083 ± 0.05
% Difference		-12.4%	0.82%	10.2%	-5.02%
Statistically Significant Change?		Yes	No	Yes	No

SO_2 emissions were about 13 percent lower while combusting the blended fuel, which correlates well with the approximately 15 percent biomass to coal ratio. The reduction in SO_2 indicates that co-firing woody biomass may be a viable option for reducing SO_2 emissions without adding emission control technologies. NO_X emissions had a statistically significant increase when co-firing. Increases are presumably due to the higher temperatures within the boiler that were experienced while firing the dryer, lighter blended fuel. Changes in CO and CO_2 emissions were not statistically significant.

Table S-3. Particulate Emissions (lb/MMBtu)

Test ID	Fuel	Total Particulate	Filterable PM	Condensable PM
Baseline 1	100 % Coal	0.090	0.038	0.051
Baseline 2		0.039	0.023	0.016
Baseline 3		0.054	0.031	0.022
Baseline 3		Not Tested		
Cofire 1	Blended Fuel (85.1 coal: 14.9 wood)	0.046	0.026	0.021
Cofire 2		0.044	0.023	0.020
Cofire 3		0.041	0.023	0.018
Baseline Averages		0.061 ± 0.03	0.031 ± 0.008	0.030 ± 0.02
Cofire Averages		0.044 ± 0.003	0.024 ± 0.0018	0.020 ± 0.0012
Absolute Difference		-1.71E-02	-7.03E-03	-1.01E-02
% Difference		-28.1%	-22.8%	-33.9%
Statistically Significant Change?		No	No	No

Although not statistically significant, particulate emission fractions were generally lower while co-firing the blended fuel. This is likely caused by the lower ash content of the blended fuels. It could also be the result of better combustion or better ESP performance due to changes in firebox temperatures or flyash characteristics.

Metals emissions were relatively low during all test periods. The only statistically significant change in metals emissions was a decrease in selenium. Emissions of HCl and HF were considerably lower during co-firing decreasing by approximately 9 and 29 percent, respectively.

Fly Ash Characteristics

Changes in ash characteristics were generally small, which is favorable for most operating systems (ash handling systems would not be expected to be impacted by co-firing at this rate). Carbon content and ash loss on ignition were both reduced significantly during biomass co-firing, although neither ash met the Class F requirements for use in concrete. Quantitative flyash results are voluminous and not presented here, but can be viewed in the main body of the report in Tables 3-7 through 3-9.

Biomass co-firing during this verification did not impact the quality of the ash with regard to fly ash TCLP metals (40 CFR 261.24) and Class F Requirements (C 618-05). Metals content of the ash was well below the TCLP criteria during all test periods and changes were not significant. The ash generated during co-firing did have a significantly higher SO_3 content, but was still well below the Class F requirement.

Sustainability Issues

- The wood pellets used for testing at the University of Iowa were produced from waste wood waste at a rate of 4.5 tons per hour. The equipment used to produce the pellets is rated at 250 horsepower and was operated at 80 percent of capacity. Based on electrical consumption of 0.746 kWh/hp multiplied by 200 hp, the energy use per hour to produce the pellets was 149.14 kWh or 33.14 kWh/ton. Based on an Energy Information Administration emission factor for Michigan (location of the production facility) of 1.58 lbs CO_2/kWh, CO_2 emissions per ton of pellets produced is 52.36 lbs.

- Wood-based pellets were transported from Battle Creek Michigan to Muscatine, Iowa (where the University of Iowa's coal supplier is located). 43 tons of wood-based pellets were shipped with two trucks using 350 Cummins motors. The trucks averaged 6.5 miles per gallon. The distance from Battle Creek to Muscatine is 345 miles. Therefore:

  345 miles * 2 trucks = 690 miles, divided by 6.5 mpg = 106.15 gallons, divided by 43 tons fuel = 2.47 gallons/ton.

  Renewafuel has a 28-acre site for possible future operations in Anamosa, Iowa. The distance from Anamosa to Muscatine is 65 miles. Here, Renewafuel can load as much as 25 tons of fuel per truck. Assuming use of the same truck with 6.5 miles per gallon the fuel used per ton of fuel transported from Anamosa to Muscatine, fuel usage from Anamosa is then:

  65 miles, divided by 6.5 mpg = 10 gallons, divided by 25 tons per truck = 0.4 gallons/ton

- Based on an Energy Information Administration emission factor of 19.564 lbs CO_2/gallon, CO_2 emissions per ton of pellets transported to the facility are:

  48.3 lbs/ton for Battle Creek (2.47 gal fuel /ton pellets * 19.564 lbs CO_2/gal).
  7.82 lbs/ton for Anamosa (0.4 gal/ton * 19.564 lbs CO_2/gal).

- Based on data generated during this testing, the CO_2 emission rates while firing straight coal and blended fuel (at a blending rate of approximately 15 percent wood by mass) were 205 and 207 lb/MMBtu, respectively. However, combustion of Renewafuel wood pellets, which are comprised of biogenic carbon—meaning it is part of the natural carbon balance and will not add to atmospheric concentrations of CO_2—emits no creditable CO_2 emissions under international greenhouse gas accounting methods developed by the IPCC and adopted by the CFPA [6]. The slight increase in CO2 emissions is likely also impacted by the increased mass fuel feed rates during co-firing. By analyzing the heat content of the coal and the wood, the total boiler heat input for the test periods, and boiler efficiency, it was determined that approximately 10 percent of the heat generated during co-firing test periods is attributable to the Renewafuel pellets fuel. It is therefore estimated that the CO_2 emissions offset during this testing is approximately 10 percent, or 20.7 lb/MMBtu at this co-firing blend.

- UI Boiler 10 typically operates in the 160 to 190 MMBtu/hr heat generating rate. Assuming an availability and utilization rate of 80 percent for Boiler 10, this would equate to estimated annual CO_2 emission reductions of approximately 11,000 to 13,000 tons per year. CO_2 offsets from use of wood pellets could be even greater had the analysis included emissions associated with coal mining and transportation.

- Regarding use and or disposal of fly ash, biomass co-firing did not impact either sustainability issue since the quality of the ash with regard to fly ash TCLP metals and Class F Requirements was unchanged.

Details on the verification test design, measurement test procedures, and Quality Assurance/Quality Control (QA/QC) procedures can be found in the Test Plan titled *Test and Quality Assurance Plan – Environmental and Sustainable Technology Evaluation Biomass Co-firing in Industrial Boilers.* (Southern 2006). Detailed results of the verification are presented in the Final Report titled *Environmental and Sustainable Technology Evaluation Biomass Co-firing in Industrial Boilers – University of Iowa* (Southern 2007). Both can be downloaded from the Southern's web-site (www.sri-rtp.com) or the ETV Program web-site (www.epa.gov/etv).

Signed by: Sally Gutierrez – April 28, 2008	Tim Hansen – April 3, 2008
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