EERC RESPONSE TO TECHNICAL REVIEWERS' COMMENTS
R011-B

Pilot-Scale Testing to Evaluate the Effects of Biomass Cofiring Combustion on CMMs at Low Mercury Concentrations

Energy & Environmental Research Center
Principal Investigator: John Pavlish
Request for $247,000; Total Project Costs $494,000

1. **The objectives or goals of the proposed project with respect to clarity and consistency with North Dakota Industrial Commission/Renewable Energy Council goals** are: 1 – very unclear; 2 – unclear; 3 – clear; 4 – very clear; or 5 – exceptionally clear.

Reviewer 2A (Rating: 4)
The goal of this project is to test two instruments to see if they detect the levels of mercury continuously in flue gas when biomass is co-fired with coal.
The goal is clearly set. The objectives are consistent and integrated with the goal. The consistency of the goal with the NDIC/REC's goals, however, is indirect due to the nature of such a project – the project is to test instruments that may serve as a monitoring tool for projects that involve biomass/ bioenergy.
The significance of such a project is not well justified, except mentioning that the data will be used for policy/ regulation purpose.

Reviewer 2B (Rating: 2)
The objective is very clearly stated: to evaluate instrumentation for measuring mercury emissions while co-firing coal and biomass. The consistency with the NDIC/RE Council is less evident. Biomass has inherently low mercury content and to the extent it is co-fired with coal, mercury emissions from a power plant will decrease. The success of the stated objectives will not impact the greater use of biomass in power generation.

Reviewer 2C (Rating:4)
The project proposes to provide analytical information on the accuracy of CMM's during biomass gasification. This will provide baseline information for new technologies or methodologies.

Response: *The EERC thanks the reviewers for their time and the REC for the opportunity to provide a response to their comments. In general, we note the constraints implied with the allowable page limit for the proposal. We appreciate the ability to provide greater depth of information at this time.*

To clarify, we will be evaluating two continuous mercury monitors (CMMs), one from Tekran and the other from Thermo. Data from these instruments will be compared to data obtained using the U.S. Environmental Protection Agency's (EPA) reference dry sorbent trap method. These data will be used to determine if the CMMs have the ability to measure low- level mercury concentrations, which are expected when cofiring biomass. Additionally, the project will provide emission data that can be used by power or distributive energy systems that either cofire with

biomass or use 100% biomass fuel. The EERC is currently evaluating these CMMs in a separate project at or below 1.0-µg/dNm^3 concentrations when combusting 100% coal. Some challenges have been identified, and the EERC is working with the vendors to resolve the challenges. There are significantly more uncertainties when measuring in a biomass-derived flue gas, with its high alkali content, especially potassium, and relatively high halogen content. Both of these components are introduced with biomass, which this project hopes to quantify.

North Dakota is consistently placed at or near the bottom of the list for states that utilize biomass in power generation; however, greater emphasis is being placed on various modes of distributive energy, increasing the use of biomass across the state for "opportunity" fuels. In the near term, a utility maximum achievable control technology (MACT) rule is expected to be released by EPA that will require significant reductions in mercury emissions. One strategy that is consistently mentioned as an option to decrease these emissions is to cofire existing boilers with biomass. It is expected that the Boiler MACT rule that was just released gives some indication that significant reductions will be required under the Utility MACT rule. Until the Utility MACT is released, utilities are operating under the expectation that they will likely be expected to have mercury emissions less than 1.0 µg/dNm^3 and that they will need to instruments that provide reliable and accurate measurement at this low concentration.

As Reviewer 2B notes, mercury concentrations are typically very low in biomass—often 1/10 to 1/100 the concentrations present in most coals; this is will not preclude these units from measuring and validating low mercury emissions, whether biomass- or coal-derived. Further, previous CATM work has demonstrated that biomass fuels often exhibit wide variability depending upon factors such as harvest season or underlying geology of the soil.

It is widely assumed that cofiring with biomass lowers the overall emissions because the biomass mercury concentrations are lower, thus diluting mercury concentrations from the coal. This misunderstanding of the chemical factors that affect emissions has, unfortunately, been widely disseminated. In fact, several factors influence the emissions of trace metals, particularly for mercury. Changing the chemistry affects the volatility of other elements and may result in the formation of aerosols or very fine particulate matter, which may actually increase overall emissions. These secondary products will likely increase the complexity of measuring mercury at very low concentrations and thus justify a thorough evaluation.

As noted above, in a separate project, the EERC has been evaluating the performance and reliability of CMMs at very low concentrations using coal as the feedstock, which has provided information to ensure that modifications will ensure reliable low-mercury concentrations. This is even more important in the biomass-derived flue gas because of the greater uncertainties involved.

2. **With the approach suggested and time and budget available, the objectives** are: 1 – not achievable; 2 – possibly achievable; 3 – likely achievable; 4 – most likely achievable; or 5 – certainly achievable.

Reviewer 2A (Rating: 5)

The project's nature is instrumentation testing and the objectives are achievable with high certainty.
The outcome of the project will be reporting the applicability of the instruments tested. The project itself does not to propose to work with the instrument manufacturers for possible re-tuning, re-calibrating, or re-designing if the machines fail to detect the expected levels of mercury or if the accuracy is not met.

Reviewer 2B (Rating: 5)
The objectives will clearly be obtainable as there is no "stretch goals" or research questions being investigated. The PI's have built an excellent facility for investigating toxic metal emissions from coal combustion and gasification and will be able to perform the promised objectives.

Reviewer 2C (Rating: 4)
The equipment, instrumentation and resources are available to complete the proposed objectives.

Response: *The EERC wishes to correct the statement made by Reviewer 2A. The EERC has a very long history of developing mercury measurement techniques spanning almost two decades that includes development and validation of many currently accepted measurement techniques, including the Ontario Hydro method, EPA Method 30B (sorbent traps), the Appendix K sorbent trap method, and various continuous emission monitors. Much of this work has been conducted through the Center for Air Toxic Metals® (CATM®) and is documented in their reporting (see http://www.undeerc.org/catm/area2_catm.htm, for partial overview of recent work). This has involved significant work with many vendors of various measurement technologies, with the goal of ensuring that the power and industrial sectors have reliable measurement tools and that the information that is gained benefits the larger stakeholder community. Often, this evaluation and feedback has been integrated into projects that evaluate mercury reduction strategies, with the instrument evaluation a secondary or tertiary consideration. In some cases, such as the proposed project, the effort requires that measurement validity and reliability be the sole focus, with a test matrix that is tightly controlled to ensure proper quality assurance/quality control (QA/QC).*

In all cases, if a vendor provides instrumentation, project feedback has been shared with them to provide invaluable direction for modifications to ensure better performance, greater reliability, proper programming of the instruments, and feedback regarding overall operability. As in the past, this information is critical to the modifications needed to meet operational difficulties that are identified, as well as pending regulations, whether at the federal or state level.

While we have not shown the vendor's contributions as formal cost share in this proposal, rest assured that the major CMM and sorbent trap vendors have been involved in the previous project and will be involved in this evaluation as well. Problems or issues identified in this project will be observed and shared in a transparent manner with the instrument vendors and sponsors.

3. **The quality of the methodology displayed in the proposa**l is: 1 – well below average; 2 – below average; 3 – average; 4 – above average; or 5 – well above average.

Reviewer 2A (Rating: 3)
There is a lack of details on how exact the testing will be done and how the data will be analyzed/ interpreted. There are no details on how the machines or data detected by the machines are to feed back to the system for improving co-firing for mercury control purpose. It is just to test "what it is" situation.
It seems that the project team has done similar work previously. How this proposed work is different from their previous work is not clearly stated. The proposal does not show data of the mercury levels in the coal and/or biomass, nor justifications on how such levels will affect mercury levels in flue gas and thus the monitoring by the machines.

No industry partners are involved, which are said to be benefited from this project. To this reviewer, the to-be-benefited industry by this project would the mercury machines manufacturers, not the biomass co-firing companies because the applicability of such machines is limited by the machines themselves, not how the co-firing is conducted.

Reviewer 2B (Rating: 4)
Accurate measurement of mercury emissions is notorious difficult. The co-PI's have developed methodologies for accomplishing these measurements, for which I give them high marks. I am a little disappointed that what is promised, though, is little more than routine data collection.

Reviewer 2C (Rating: 3)
Could have more detailed information on PTC operating conditions during the mercury emission testing.

Response: *A test plan will be provided in the presentation. In addition, prior to initiating any work, a very detailed test plan will be developed in cooperation with the researchers who are completing the current evaluation of CMMs; this test plan will be provided to project sponsors for review and approval prior to initiating controlled testing at the pilot scale. Test parameters, such as the origination of the biomass to be tested, will be planned with sponsors. Table 1, below, shows the concentrations of some biomass materials that are common to North Dakota as identified in earlier projects.*

Table 1. *Mercury Content in Biomass*

Alternative Fuels – Biomass	*Sample*	*Moisture, wt%*	*As Recd Hg, g/gram*	*H_2O-Free Hg, µg/gram*
Wheat 1	*Kernel only*	*10.83*	*<0.0004*	*<0.0004*
Sunflower Hulls	*Hull only*	*6.88*	*0.0009*	*0.0010*
Sunflower Stover	*Stover*	*16.04*	*0.0016*	*0.0019*
Soybeans	*Bean only*	*4.84*	*<0.0004*	*<0.0004*
Corn	*Kernel only*	*8.09*	*0.0010*	*0.0011*
Minnesota Hybrid Poplar	*Wood without leaves*	*4.54*	*0.0040*	*0.0042*
Switchgrass	*Stover*	*5.64*	*0.0040*	*0.0042*
LaCrosse Hybrid Willow	*Wood only*	*5.54*	*<0.0006*	*<0.0006*
Sugar Beet Pulp	*Beet waste*	*8.27*	*<0.0004*	*<0.0004*
Cattails (Typha)	*Stalk w/o fruit*	*8.09*	*0.0836*	*0.0910*
Flax straw	*Plant*	*6.24*	*0.0060*	*0.0064*
Bromgrass	*Plant*	*5.91*	*0.0091*	*0.0097*
Rice Hulls	*Hulls*	*6.04*	*0.0020*	*0.0021*
NIST 1547 Peach Leaves (0.8)	*Leaves*	*4.23*	*0.0253*	*0.0264*

As Reviewer 2A notes, the EERC is just concluding an evaluation of CMM performance for coal-derived flue gas. The data from the previous project will provide a baseline comparison for this project.

As noted above, vendor involvement is critical to the outcomes of this project, both in the actual side-by-side comparisons and in the modifications that are likely to serve the needs of those who use biomass for power or combined heat and power production.

4. **The scientific and/or technical contribution of the proposed work to specifically address North Dakota Industrial Commission/Renewable Energy Council goals** will likely be: 1 – extremely small; 2 – small; 3 – significant; 4 – very significant; or 5 – extremely significant.

Reviewer 2A (Rating: 2)
The project is to test the tools for monitoring the co-firing system. The findings form this project would provide information for instrumentation manufacturers rather than the biomass co-firing companies.

Reviewer 2B (Rating: 1)
Demonstrating that mercury emission measurement methodologies developed for coal combustion will also work for co-firing will do virtually nothing toward increasing the use of biomass in electric power generation. The bottlenecks for co-firing involve feedstock logistics, co-feeding of coal and biomass, and particulate emissions.

Reviewer 2C (Rating: 4)
The proposed work meets the criteria of the NDIC objectives to provide baseline information that could help the advancement of biomass/coal combustion. The information will provide utilities the instrumentation resources to comply with mercury emission levels standards.

Response: *We agree with Reviewer 2C in that the outcomes of this project will benefit those who must provide defensible mercury concentration values to regulators. Often, vendors who provide biomass must generally provide some guarantee of emissions that will result from firing or cofiring with their product. At this point, it is our position that there is no continuous method by which to provide these data.*

When you consider that CMM values are often used to modify operations in near-real-time, and that at full compliance with regulatory limits, the changes will be small, it is even more important that accurate low-level mercury measurement be obtained.

We agree with Reviewer 2B that there are several logistical hurdles that must be overcome for greater adoption of biomass. But since inclusion of biomass changes the chemistry of emissions, particulate matter vapor-phase emissions will be affected, and the potential for biases to be introduced is increased.

5. **The principal investigator's awareness of current research activity and published literature as evidenced by literature referenced and its interpretation and by the reference to unpublished research related to the proposal** is: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.

Reviewer 2A (Rating: 3)
The proposal does not provide a thorough literature review on the development of similar mercury detecting machines. This reviewer is unclear but assumes that their awareness is adequate.

Reviewer 2B (Rating: 2)
Only one reference is provided to the literature.

Reviewer 2C (Rating: 4)

Response: *We would provide references and citations, but data regarding the performance of CMMs in biomass-derived combustion flue gas are not available, hence, the need for this project. We would direct the reviewers to the CATM Web site (www.undeerc.org/catm/) and previous reports for further discussions of analytical techniques evaluations and development conducted by EERC staff.*

The citation for the draft report cited under Items 1 and 2 is below.

Laudal, D.L., Dene, C., Aurelio, I., Pavlish, J.H., Botha, F. *Determining the Variability of Continuous Mercury Monitors (CMMs) at Low Mercury Concentrations.* Energy & Environmental Research Center: Grand Forks, ND. Draft Final Report to the Illinois Clean Coal Institute, EPRI, and the U.S. Department of Energy. Feb 2011.

6. **The background of the investigator(s) as related to the proposed work** is: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.

Reviewer 2A (Rating: 4)
The PIs have strong background in conducting similar testing. The expertise and capability of the PIs' institution are outstanding.

Reviewer 2B (Rating: 5)
John Pavlish, Senior Research Advisor and Director of EERC's Center for Air Toxic Metals program is well qualified to lead the project and he has assembled a good team.

Reviewer 2C (Rating: 4) <no comment>

Response: *We thank the reviewers for their confidence in our abilities. It should be noted that Mr. Pavlish previously was a Senior Research Manager for biomass research and thus has a very broad scientific and engineering background to lend to this evaluation.*

7. **The project management plan, including a well-defined milestone chart, schedule, financial plan, and plan for communications among the investigators and subcontractors**, if any, is: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – very good; or 5 – exceptionally good.

Reviewer 2A (Rating: 3)
Besides the PI and co-PIs, there are at least five technical personnel involved in this project as indicated by the budget. However, their roles are not discussed at all.

Reviewer 2B (Rating: 4)
The North Dakota EERC has notable experience in managing research projects in the energy field.

Reviewer 2C (Rating: 4)
The project management plan is clear for the proposal.

Response: *The limited space allocated to the proposal does not lend itself to in-depth discussions of the personnel involved. This evaluation involves, to a small degree, those researchers who were involved in the previous evaluations, in particular to ensure that comparative data are generated. This involvement will be further clarified in the test plan, which will again involve previous researchers noted so that "lessons learned" in the previous project are applied to testing and evaluation on this project.*

Although not outlined in the proposal, CMM vendors will be involved in the project as well to ensure that outcomes of the project result in instruments that can perform as needed.

8. **The proposed purchase of equipment** is: 1 – extremely poorly justified; 2 – poorly justified; 3 – justified; 4 – well justified; or 5 – extremely well justified. (Circle 5 if no equipment is to be purchased.)

Reviewer 2A (Rating: 5) No equipment is proposed.

Reviewer 2B (Rating: 5)

Reviewer 2C (Rating: 5)

9. **The facilities and equipment available and to be purchased for the proposed research** are: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – notably good; or 5 – exceptionally good.

Reviewer 2A (Rating: 4)
The facilities at the PIs' institution are exceptionally good. The capabilities of the mercury detecting machines, however, are uncertain in terms of accuracy and variability which are proposed to be tested in this project.

Reviewer 2B (Rating: 5)
EERC has excellent facilities for this work.

Reviewer 2C (Rating: 5)
The EERC facilities have the capabilities to complete the proposed project.

10. **The proposed budget "value"[1] relative to the outlined work and the financial commitment from other sources** is of: 1 – very low value; 2 – low value; 3 – average value; 4 – high value; or 5 – very high value. (See below)

Reviewer 2A (Rating: 3)
It seems inappropriate to this reviewer that the proposal intends to support a whole team with significant amount of hours out of a small machines testing project. The budget requested does not reflect the actual work to be accomplished.

The requested match is not secured.

Major matching is said to be from DOE in a future proposal with the condition that this proposal be funded by NDIC/REC. This reviewer is highly in doubt that DOE would fund such a project as it is proposed in this project.

Reviewer 2B (Rating: 3)
Pilot plant work is significantly more expensive than bench top studies. Nevertheless, one half million dollars to determine whether methodologies developed for measuring mercury emissions during coal combustion will also work for co-firing does not strike me as much return on investment in renewable technologies.

Reviewer 2C (Rating: 3)
The budget seems reasonable for the requested project.

[1] "Value" – The value of the projected work and technical outcome for the budgeted amount of the project, based on your estimate of what the work might cost in research settings with which you are familiar.

Response: *The proposed pilot-scale testing involves a tightly controlled test matrix with several concurrent measurement instruments/techniques being conducted, resulting in side-by-side comparisons of CMMs. This is no trivial test evaluation and involves several researchers who are highly skilled in the operation of both the combustion unit (to ensure very stable operating conditions) and the instruments themselves.*

Regarding the match, the CATM Affiliate dollars are held in reserve and can be made available immediately pending NDIC REC's decision on this proposal. Matching U.S. Department of Energy (DOE) funding is in place through the EERC–DOE joint venture program. The EERC simply needs to seek DOE project approval. The EERC has years of experience working with DOE and understands the type of projects that DOE will approve under the joint venture program. Thus the EERC is confident of existing match for NDIC's funding.

10a. **Financial commitment from other sources – A minimum of 50% of the total project must come from other sources to meet the program guidelines**. Higher priority is to be given if the application has private industry investment equal to or at least 50% or more of total cost.

The minimum 50% cash match is demonstrated.

Section C. **Overall Comments and Recommendations:**

Please comment in a general way about the merits and flaws of the proposed project and make a recommendation whether or not to fund.

Reviewer 2A (Funding May Be Considered)

(1) This is a machine testing project, which has an application in biomass-coal co-firing facilities. The machines do not feedback for reducing mercury levels in biomass co-firing.

(2) The project will not lead to significant outcomes in the areas of bioenergy, biofuels, and bioproducts as expected in the NDIC/REC's goals.

(3) Successful accomplishment of the proposed work may provide useful information for making policy and regulations in mercury control/ monitoring, but not definitely necessary.

This reviewer recommends that the proposal be funded depending the availability of funds. However, it is suggested that the budget be revised to reflect the actual work.

Reviewer 2B (Do Not Fund)
Although the co-PI's are well qualified to do the work and EERC has the facilities to successful meet the project objectives, I cannot support this proposal. North Dakota has only limited resources to seed renewable energy technologies in the state. Evaluating instrumentation to measure a pollutant emission that is not a problem for biomass feedstocks is a poor use of these limited funds. If the goal is to promote co-firing, then support projects that address biomass logistics for power plants, feeding of biomass into boilers, or particulate emissions from biomass combustion.

Reviewer 2C (Fund)
The proposed project is critical for future EPA mercury emission requirements to reduce environmental impacts for biomass/coal fired combustion. The study will also provide instrumentation accuracies to manufactures of CMM analyzers. Overall the project will provide valuable information/ data to utilities that are currently utilizing coal-biomass blends. The projected should be funded.

Response: *The EERC agrees with Reviewer 2C in that the proposed project is critical to address future state and federal (EPA) mercury emission requirements/regulations and to demonstrate compliance with these regulations. As mentioned, the Boiler MACT has just recently been promulgated and the Utility MACT is expected to be released by EPA March 15th. Both of these rules require the reduction of mercury and accurate measurement to demonstrate compliance. While cofiring biomass may result in decreased emissions, because of its relatively high potassium and halogen content, it may introduce CMM challenges and biases. The focus of this project is to demonstrate that commercial CMMs can indeed be used to accurately and reliably measure mercury at low mercury concentrations (below 1.0 µg/dNm^3), which are expected when cofiring with biomass, and which may be required by future regulations.*

With regard to Reviewer 2A's comments, please see Item No. 1. CMMs provide near-real-time measurements of emissions, which CAN provide a signal to adjust operational parameters of the unit. Since many biomass-cofired systems have discrete feed mechanisms for the biomass, the signal can be used to increase or decrease biomass feed rates.

In addition, cofired systems will need to comply with regulatory limits for mercury, especially if the system is sized for utility-scale power.

The budget that is included is commensurate with the budget that was required to perform a similar project which was performed in the previous fiscal year.