Lignite Research Council

Re: Proposal submitted by Calnetix Inc April 1, 2009

"Application of Waste Heat Recovery Generation, Great River Energy Coal Creek Plant"

Proposal Number: **LRC-LXVI-B**

Addendum to Proposal

Submitted in Response to Long Application Rating Forms by Peer Reviewers

May 8, 2009

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This addendum provides further information on the above proposal, in order to address specific comments and questions of the peer reviewers.

The following are addressed within this Addendum:

1. Further explanation of the purpose of the WHG100 proof of concept demonstration prior to testing the large unit.

2. Further information on the plan for manufacturing the large unit in North Dakota.

3. Industry commitments.

4. DOE funding.

5. Specific responses to questions raised by reviewers not answered elsewhere above:

   A. Need for preliminary mass and energy balances and utilization of 10% of waste heat.

   B. Superior efficiency of Calnetix unit.

   C. Issues associated with scaling up the 100kW unit.

   D. Cost of the larger unit.

1. Further explanation on purpose of WHG100 proof of concept demonstration prior to testing the larger unit

Concern was raised regarding the validity of utilizing Calnetix's existing WHG100 unit for the proof of concept trial as opposed to only developing, testing, and demonstrating with a larger unit.

Calnetix has commercialized a waste heat recovery generator capable of generating 100 to 110kW (net). The unit has been successfully applied to various applications such as flares, industrial boilers and exhaust heat from gas turbines. The unit is factory built and pre-packaged as a 'plug-and-play' solution, but it also requires the installation of a heat exchanger and condensing source, and connection to the electrical grid. Production of electricity from a heat source, and connection to the grid, are relatively straightforward processes, however the connection of the unit to the heat source raises issues which need to be dealt with on a site by site basis (e.g. temperature, heat exchanger specification, heat flow rates, direct or indirect connection to the heat source, potential contaminants in the waste heat source and their corrosive effects on the heat exchanger).

Calnetix has applied its unit to various applications, but to date, not at a coal fired power plant environment. We believe there will be unique issues at the plant related to accessing the heat source and determining a viable configuration for the waste heat unit, and believe it will be beneficial to work through and determine these at smaller

demonstration level before moving to accessing them with the larger unit. In this sense, the demonstration is not so much about the production of electricity from the waste heat sources at the plant (if we can successfully access these heat sources we know that the unit will produce power), but rather validating that it is possible to access and utilize the low temperature waste heat streams at the plant in an economical way.

Accordingly, in the context of proving the concept of Calnetix waste heat recovery generation at the Coal Creek facility, the quantity of waste heat to be recovered is a secondary issue, the primary concern is to understand the unique challenges related to this specific application. The fact that the base WHG100 unit is already qualified to be reliable provides us the opportunity to minimize any distractions that could arise from potential problems related to the unit itself and allow us to concentrate on addressing application related challenges.

In addition, the larger unit development will not be complete, and testing of the larger unit will not begin, for 24 months. During that time, the installation of the smaller unit at Coal Creek gives Calnetix and GRE an opportunity to:

- understand the challenges of installing a waste heat unit at a power plant site;
- learn specific practical issues that inevitably were not anticipated prior to installation (all of which should save time and cost when installing the larger unit);

- gather data which can be shared with other utilities and lignite plants and which could be fed into the development of the larger unit
- get feedback from other lignite users as to whether and how the larger unit could be utilized at their sites.

2. Further information on the plan for manufacturing the large unit in North Dakota

A question was raised regarding the likelihood of the unit being manufactured in ND given that Calnetix has plants in California and Florida.

Manufacturing the unit in North Dakota is a core piece of the Calnetix plan, and Calnetix has recently concluded negotiations with Steffes, Inc of Dickinson, ND to act as the exclusive manufacturer of the unit for North American applications. Competitive labor and operating costs, potential in-state support, proximity to utility waste heat sources, and a central location for shipping throughout North America were all considerations in this decision. In addition, the development and testing of the larger waste heat recovery unit will require a test bed with a 10MW+ heat source, which we anticipate will be fired by natural gas. It is not possible in California, and very difficult in Florida, to obtain permits to install a dedicated gas fired heat source of this size in an industrial area. We believe this will be achievable in North Dakota, and it is a significant factor in deciding to manufacture there. The President and COO of Steffes, Joe Rothschiller, will attend the meeting on May 19 to discuss his firm's involvement in the project and answer any questions. Our seriousness regarding Steffes's involvement in this project is underscored

by our current negotiations to appoint Steffes as a distributor of the current 100kW product.

3. Industry commitments.

Concern was expressed regarding a perceived lack of financial commitment from industry.

GRE is the industry 'sponsor' of the project, and will be contributing its facilities and substantial employee to the project. However, due to its R&D budget being fully allocated for 2009, GRE will not be contributing cash to Stage One of the project. Assuming that the project progresses to Stage Two, Calnetix will be discussing the potential for GRE, as well as other members of the Lignite Research Council with a potential interest in the outcome of the project, about providing cash contributions to support this Stage.

4. DOE funding

A reviewer requested that the proposal should address the need for DOE funds to ensure the project can be completed in an orderly manner.

Calnetix is currently seeking DOE funding for the development and commercialization of a 1-2MW waste heat recovery generator. For this purpose, it has assembled a 'team' consisting of Calnetix (engineering/development), GRE (Utility partner), Steffes, Inc (manufacturing) and HDR

Engineering (power plant and thermal engineering consultant). It is also likely that NDSU and/or UND will be involved in applied research on unit efficiency. The formal DOE proposal is likely to be made under the DOE's Industrial Technologies Program administered by the Energy Efficiency and Renewable Energy (EERE) division of the DOE. Considerable funds now exist for energy efficiency initiatives under the recently passed American Recovery and Reinvestment Act. Although Calnetix has no certainty regarding the timing of funding, its aim is to secure this by the end of 2009.

5. Specific responses to questions raised by reviewers, not answered elsewhere above

A> **Need for preliminary mass and energy balances and utilization of 10% of waste heat**: Although Calnetix has made one site visit to Coal Creek Station, and believes that sufficient low level waste heat exists to power a larger unit, it does not have the knowledge or industry background to determinate, even on a preliminary basis, the specific mass and energy balances of the plant. For this we require the assistance of specialist engineers such as HDR. The request for Stage One funding is to be able to commission HDR to carry out this analysis in a detailed fashion and determine the viability of accessing the waste heat streams at the plant.

Regarding accessing 10% of the heat source at the plant, this figure was an estimate based on discussions with GRE engineers and Calnetix's own assessment following the site visit to Coal Creek. To this extent the number is not

substantiated by any formal research. This should have been made clear in the application and we apologize that this was not set out in more detail.

B> **Superior efficiency of Calnetix unit**: Under typical conditions, the Calnetix WHG100 has a net heat to electricity conversion rate of 15-17%. The figure 16% was used in the application as the middle of this range. There are currently two companies active in the US that have developed 1MW+ organic rankine cycle units. These are Ormat from Israel and United Technologies (UTC). Based on data from the EPA CHP partnership program, the efficiency of the ORMAT system has been identified to be 11%. There are numerous studies published on the UTC unit applied to Chena Hot Springs in Alaska that place its efficiency at 8%. According to the University of North Dakota study on geothermal waste heat recovery systems, UTC states its unit efficiency at 10%.

C> **Issues associated with scaling up the 100kW unit:** Calnetix considers the scaling up of the current 100kW unit to 1-2MW to be a complex engineering task, but one for which it currently has technology, capabilities and experience.
As stated in the proposal, Calnetix currently produces a 'Frame 2' (1.2 - 2MW) high speed generator with magnetic bearings and associated power electronics. These three components, which would form the core of the large unit, share the same basic topology and underlying technology as the components in the 100kW version. Because the components have been developed and are well

understood by Calnetix, a major piece of the development of the larger unit has already been done.

The Organic Rankine Cycle aspects of the development are essentially a scaling up of the same layout and engineering approach employed in the 100kW unit, and having engineered the 100kW unit internally, Calnetix has a good understanding of the thermal science issues of scaling the smaller unit to a 1MW+ range. Like the 100kW unit, the intent here is to utilize existing hardware where possible, and refrigeration industry standard components (piping, tanks, valves etc).

Nevetheless, based on a preliminary feasibility study conducted in 2007, certain issues will need to be addressed during the development design phase including:

- whether to use a two-stage axial expander as opposed to the current radial flow expander with corresponding change in pressure sealing schemes;
- keeping pressures below 300 psia in order to utilize refrigeration industry standard pipes, valves, pumps etc. for cost and availability;
- achieving 6” to 8” of max back pressure on the turbine exhaust

D> **Per kW cost of the larger unit**: Calnetix's preliminary estimates are that the larger unit could be anywhere from 0 – 20% less costly per kW. However, this has not been substantiated and we believed it was prudent to assume the same cost as the current 100kW unit. In addition, beyond a certain point the installation cost of the smaller unit will increase as the number of units increase. For example, the installation and maintenance costs of a 6MW unit utilizing four 1.5MW units are likely to be significantly less than utilizing sixty 100kW units. Accordingly, even if the basic installed cost per kW of the large unit is the same, we would still expect economies of scale at the power ranges expected to be seen at coal fired power plants.