Application of Waste Heat Recovery Generation

at

Great River Energy's

Coal Creek Station

Applicant: Calnetix Inc.

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(Director of Engineering, Calnetix, Inc)

Date: April 1, 2009

Amount Requested:

Step One: $80,000

Step Two: $250,000

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1. Abstract

Improving power plant efficiency through recovery of waste heat is not a new concept, but recent policy and regulatory shifts (efficiency and emissions mandates, renewable portfolio standards, carbon trading) and technological improvements are trending to improve the economics of recovering this heat.

Calnetix, Inc manufactures a 100-110kWe waste heat recovery generator (WHG 100) that provides superior conversion of waste heat to electricity (16% net vs. competitors at 8-12%) due to its high-speed generator and non-contact magnetic bearings. Its modular design allows repetitive manufacturing, and a cost that typically provides ROI of less than three years. Calnetix intends to use its current technology to 'scale up' the WHG100 unit to 1-2MWe. It believes that deploying this larger unit at lignite power plants could provide an economical way of improving plant efficiency, thereby helping to keep lignite coal economical and competitive as a fuel into the future.

Calnetix is currently working to obtain Department of Energy (DOE) funding for a multi-phase program, located in North Dakota, to develop and commercialize this larger unit. Calnetix seeks the support of the Lignite Research Council (LRC) for the initial validation phase of this program as follows:

Objective: Identify usable waste heat sources within a lignite power plant, validate they are sufficient to power multiple 1-2MWe units, and demonstrate the technical viability of generating electricity from one such source using Calnetix's current WHG100 unit.

Expected Results: Validation of waste heat sources at GRE's Coal Creek plant which could support multiple 1-2MWe units, and successful demonstration of 100kWe electricity generation from one such waste heat source.

Duration: 22 months.

Total project cost: Spread over two steps:

- Study to identify and quantify heat sources, and validate the viability of connecting the Calnetix unit to these sources. Total cost is $161,250 of which Calnetix seeks $80,000 (50%) from the LRC.
- Install and run the Calnetix WHG100 demo unit for proof of concept. Total cost is estimated at $735,495 of which Calnetix seeks a maximum of $250,000 from the LRC. LRC funding of this step is conditional upon Step One validation being successful, and upon funding being made available from the DOE.

Participants: Calnetix, Great River Energy and HDR Engineering.

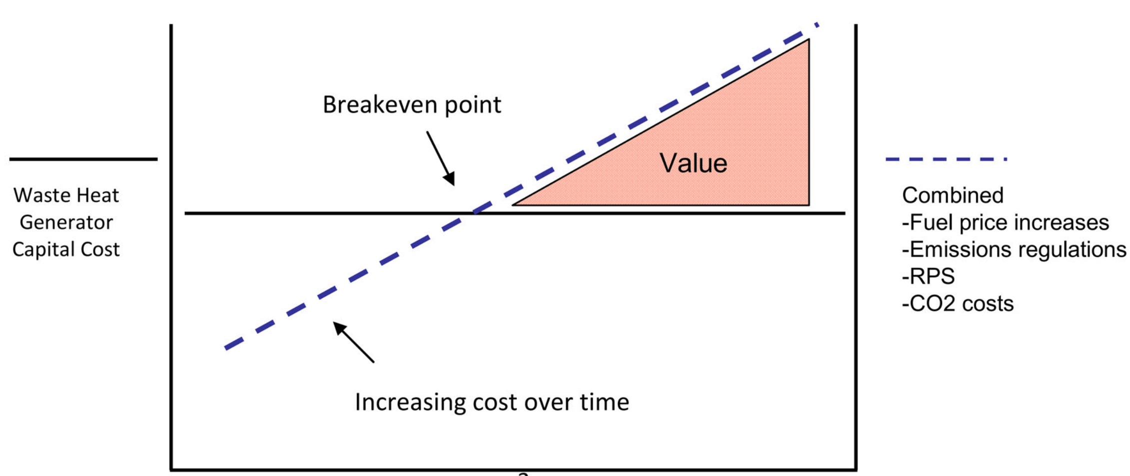
2. Project Summary

Overview

Calnetix is seeking to develop and within 36 months commercialize a 1-2MWe waste heat recovery generator, for application to low temperature heat sources at thermal power plants and industrial facilities.

Calnetix believes that a waste heat recovery generator of this power range would have value to the lignite industry. Given the lower thermal output of lignite coal, it is more challenging for lignite power plants to meet increasingly stringent emissions requirements and the cost of various carbon limitation or pricing mandates. To the extent that waste heat recovery can reduce the emissions per MWh from lignite power plants, at an attractive installed capital cost, this will keep lignite competitive, economical and maintain its relevance as part of the nation's energy needs.

This larger unit will be based upon Calnetix's existing WHG100 organic rankine cycle production unit, and is intended to share the smaller unit's modular, standardized, and factory manufactured approach. Calnetix believes this approach will allow it to keep the installed cost of the unit at an estimated $2,500/kW, lower than the custom built solutions that are currently the industry standard. Calnetix believes this low cost approach will provide increasing value as the price for emitting carbon dioxide and fitting new pollution controls to plants increase (see following illustration):



Value / Payback

Calnetix is currently working to obtain Department of Energy (DOE) funding for a multi-phase program, based in North Dakota, to develop and commercialize a 1-2MWe unit. This will be approximately a 36 month process from initial design work to commercial manufacture, and be split into the following phases:

1. Technical validation and WHG100 proof of concept demonstration.
2. Large unit development and lab testing.
3. Large unit field testing.
4. Commercialization and manufacture.

The end goal of this program is to volume produce this larger waste heat recovery unit in North Dakota. Although the unit will likely be sold and applied nationally and internationally, it is expected that the demonstration testing and initial commercial installations will be in the North Dakota region, including on lignite power plants.

Calnetix seeks the support of the Lignite Research Council for <u>Phase One</u> of this overall program, i.e. initial technical validation and WHG100 proof of concept demonstration. This is a vital first phase in the overall four phase commercialization plan.

<u>Objective</u>

The objectives of the project for which Calnetix seeks LRC support (i.e. Phase One of the overall four phase DOE program) are:

- **Step One**: together with Great River Energy and HDR Engineering, to identify usable low temperature waste heat sources within a lignite power plant, and theoretically validate that sufficient usable waste heat exists, and can be economically accessed, from one or more of these sources to power multiple Calnetix 1-2 MWe units;

- **Step Two**: install a current Calnetix WHG100 unit at one such heat source, and demonstrate the technical viability of generating electricity from it.

Step One will take the form of a formal study and written report led by HDR Engineering (Lead: Dave Schmitz), with support from Great River Energy (lead: Charlie Bullinger) and Calnetix engineers. The anticipated contents of the study are explained in further detail in Section 3 of this Application ("Project Description"). The total cost of Step One is estimated at $161,250, of which Calnetix is seeking $80,000 (50%) from the LRC. Calnetix has made an initial site visit to GRE's Coal Creek Station, and identified four low temperature waste heat streams (soot blower drain, flue gas, fly-ash and scrubber sludge) as potentially viable sources for electricity generation. This Step One study aims to confirm these initial findings, determine the amount of potential waste heat, available, assess the technical viability of generating power from these sources and make an estimate of the amount of electrical power potentially available.

Step Two will involve detailed site and installation analysis, engineering and construction work to install the Calnetix waste heat unit onsite, and ongoing monitoring and results analysis. The total cost of this step is estimated at $735,500**.**

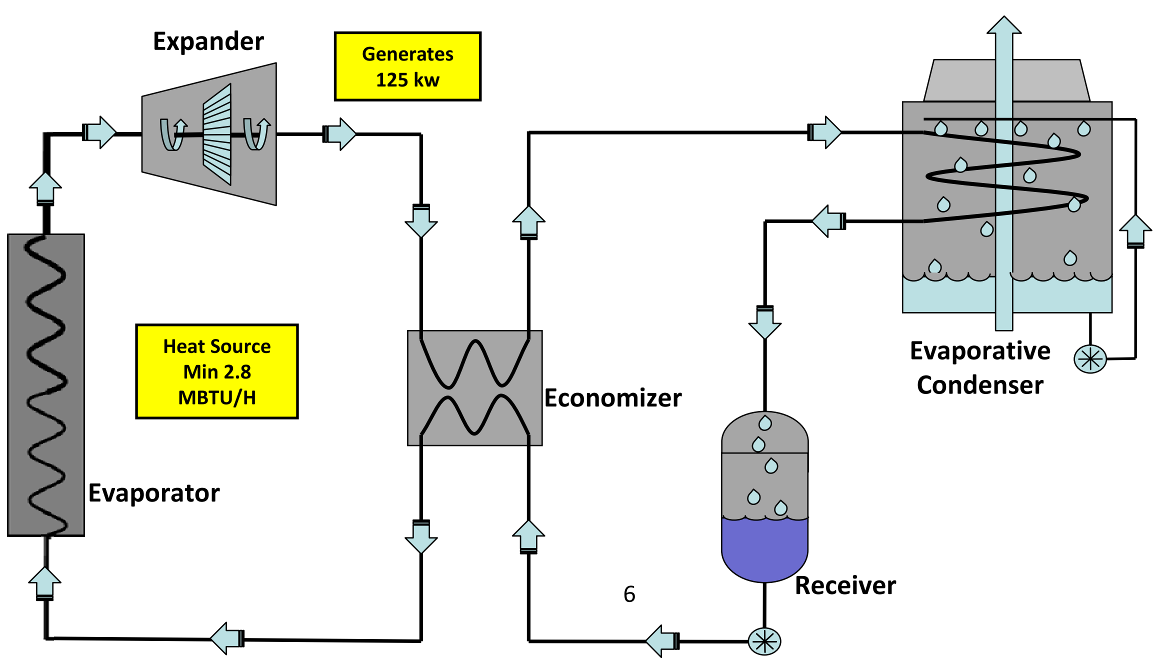
Part of the scope of Step One is to understand the high-level costs for this installation, including equipment modifications. The costs of Step Two may need to be revised following the completion of the Step One study. However, Calnetix seeks a maximum of $250,000 from the LRC for Step Two as a "not-to-exceed" amount, even if the total costs of this step end up being higher.

Calnetix also requests that funding of Step Two be made conditional upon Calnetix receiving DOE funding for the complete development of the larger unit over the four phases outline above. Although Calnetix seeks the LRC's conditional approval for funding Step Two, if DOE funding is not received, Calnetix will not request or 'draw down' these funds.

<u>Further Project Background</u>

Calnetix (www.calnetix.com) is the world leader in the development and manufacture of high speed, high efficiency permanent magnet motors and generators, with associated magnetic bearings and high frequency power electronics. Its products and capabilities range from 2kW to 10MW, and it has a particular specialty in distributed power generation from waste energy, such as waste heat, waste gases and unused kinetic energy (e.g. ship turbocharger shafts).

Calnetix produces a 125kWe gross/100-110kWe net waste heat recovery generator (WHG100) that utilizes a closed loop organic rankine cycle. This involves utilizing heat as low as 250F to gasify a low boiling point refrigerant, passing the gas across a turbine wheel attached to a generator to produce electricity, re-liquefying the gas using a condenser, and pumping it to the heat source again to complete the cycle, as shown in the following diagram:

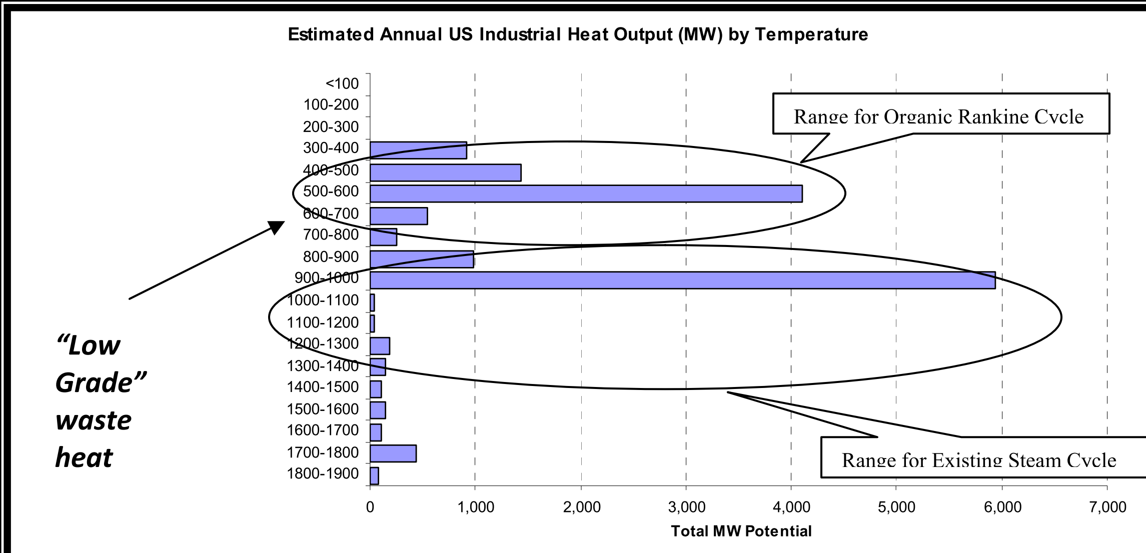


Typical applications include exhaust heat from gas turbines and internal combustion engines, industrial boilers, and flare stacks. Calnetix's WHG100 can utilize approximately 625-700kW of heat input to generate 100-110 kWe net electricity (output varies based on environmental conditions and waste heat extraction schemes). The unit is factory built and pre-packaged as a 'plug-and-play' solution requiring only the installation of a heat exchanger and condensing source, and connection to the electrical grid. This is in contrast to other commercially available waste heat recovery units, which are custom designed and engineered for each site. The current unit is pictured below:

The WHG100 is suitable for smaller industrial and distributed generation applications, and installed cost is typically in the $2500/kW range.

However, Calnetix believes that a significant opportunity exists to recover low grade waste heat from larger applications such as thermal power plants and large industrial facilities. A significant amount of waste heat is emitted by these large facilities at lower temperatures where it is not feasible to install steam turbines. These temperatures are ideally suited for refrigerant based Organic Rankine

Cycle generators, and could provide substantial additional power without using any additional fuel or creating any additional emissions.



Source: derived from U.S. EPA, National Emissions Inventory Database

Calnetix's former subsidiary and sister company Direct Drive Systems, Inc currently produces 'Frame 2' (1-2.5MWe) and 'Frame 8' (6-10MWe) motors and generators using the same high speed proprietary permanent magnet technology with non-contact magnetic bearings. These motors and generators (as shown below) are up to 90% smaller and lighter than traditional solutions, are 10-50% more efficient, and can be directly driven at variable speed from a turbine shaft.


Frame 2 **Frame 8**

Calnetix has full ownership of this generator technology for waste heat recovery, and intends to use the Frame 2 generator as the basis to 'scale up' its WHG100 unit to 1-2MW. It will apply the same technical approach and modular manufacturing philosophy, such that the larger unit can also offer a standardized 'plug-and-play' approach in order to reduce the on-site engineering cost and lead time necessary for applying it to the various waste heat sources. This is in contrast with other ORC units of this size which are custom built for each job.

Calnetix therefore aims to create something that can be 'rolled out' to the industry at a cost per kW comparable to its WHG100 unit, and deployed in scale quickly. For the lignite power industry, this could provide a viable approach to reducing its net emissions, improving efficiency in a cost effective manner.

3. Project Description

Why is the project needed?

Calnetix believes that the combined costs of future carbon taxes (cap & trade), pollution compliance costs and renewable portfolio standards will either increase the cost of power generation using lignite, or decrease the relative attractiveness of lignite generation vs. other 'renewable' alternatives. A cost effective waste heat recovery option, which improves the efficiency of lignite generation and has the potential to generate carbon credits and/or electricity that qualifies under renewable portfolio standards, should therefore be beneficial and attractive for lignite power producers.

There are six Lignite Coal power plants in North Dakota[1] with a net summer generation capacity of 3920MWe.[2] According to a 2004 study published by the Commission for Environmental Cooperation, these plants generate approximately 29.6m MWh of electricity annually.[3] Assuming the following:

- an average plant efficiency of 33%;
- of the remaining 67% of wasted energy, 10% of this is in the form of recoverable waste heat;[4]
- a net heat-to-electricity conversion 16% (the current efficiency of Calnetix's WHG 100 which Calnetix believes can be replicated in the larger unit),

could generate an extra 915,000 MWh of electricity from the waste heat at these plants without additional fuel costs or emissions penalties.[5]

[1] Taken from "The Story of Lignite", published by the Lignite Energy Council.
[2] 2006 data supplied by the Energy Information Administration.
[3] "North American Power Plant Air Emissions", Commission for Environmental Cooperation, 2004.
[4] Derived by Calnetix following its tour of Coal Creek Power Plant November 2008.
[5] See table at page 26 below for further detail.

A waste heat recovery unit may also contribute to the goals of 2007 North Dakota legislation H.B. 1506, which establishes an objective that 10% of all retail electricity sold in the state be obtained from renewable energy and recycled energy (including waste heat) by 2015. To the extent that the equipment reduces carbon dioxide emissions per MWh, it should also provide a cost saving to utilities (in the form of lower carbon costs per MWh) under the recently proposed Obama Administration cap and trade program. At an estimated cost of $13.70/ton of CO2,[6] utilization of waste heat recovery on lignite power plants in North Dakota could provide a saving of approximately $16m/year.[7]

Objective

The objectives of the project are:

- Step One: together with Great River Energy and HDR Engineering, to identify usable low temperature waste heat sources within a lignite power plant, and theoretically validate that sufficient usable waste heat exists, and can be accessed, from one or more of these sources to power multiple Calnetix's planned 1-2 MWe units;

- Step Two: install a current Calnetix WHG 100 at one such heat source, and demonstrate the technical viability of generating electricity from it.

Methodology

Step One involves identifying all possible heat sources within a lignite power plant including identifying heat sources that indirectly affect the operation of the plant (e.g., lignite drying,

[6] Price estimated by Point Carbon (industry analyst – see www.pointcarbon,com) as the assumed cost/ton of CO2 emissions allowances under the budget submitted to Congress Feb 26, 2009.
[7] See table below at page 27.

limestone production, scrubber equipment and processes). The Coal Creek plant will be used for this purpose. This Step also involves:

- validating, using Calnetix's assumed net heat to electricity conversion of 16%, that the temperature and flow of the waste heat at the identified sources is sufficient to power multiple 1-2MWe units;
- identifying if there are any significant technical issues that would either preclude installation of waste heat recovery at any of the sources or make an installation uneconomic;
- studying the effects of removing the heat from the perspective of component and overall power plant energy balance/performance;
- identifying any potential safety issues that would need addressing within the context of installing and running a waste heat recovery unit at the various sites.

A site-specific analysis will be conducted by constructing an EPC budget to include necessary items and accessories for a large unit installation, such as specifying the heat exchangers, condensers and piping that would be required to complete an installation at the most promising of the waste heat sources.

Calnetix will commission HDR Engineering to undertake much of this analysis together with engineers from Calnetix and GRE. The specific HDR deliverables under this commission are as follows:

- Site visit to obtain data, review concepts and review existing plant equipment for potential utilization. This will involve HDR personnel on-site to review location of heat sources and

- Performance modeling of the existing facility before and after the addition of the WHG installation (including potential parasitic loads required to support the installation).
- Discussions with applicable industry vendors to assess technical suitability and cost of the proposed plant modifications.
- Identification of potential technical and environmental risks and risk mitigation strategies.
- Development of process flow diagrams to identify balance of system.
- Development of high-level cost estimate for total installation, including equipment modifications and generator pricing as predicted by Calnetix.
- Development of a feasibility study report describing the potential for the proposed installation and including the results of all of the above activities.

In Step Two, the validity of Calnetix technology for lignite power plants will be demonstrated by installing and running a Calnetix WHG100 waste heat recovery generator at GRE's Coal Creek Station for 12 months. The quantity of electricity generated will be tracked with respect to run time, maintenance, and other factors in order to estimate the anticipated return on investment from the larger unit. This step will allow Calnetix to assess the performance, cost and benefits of the unit relative to the identified waste heat sources, and obtain real-life technical data which will be relevant to the development of the larger unit. Through an internet connection, Calnetix will also have the capability to monitor remotely from its Florida facility.

Following completion of the demonstration (i.e. after 12 months), Calnetix and GRE, in consultation with the LRC, will make a determination of the ongoing use of the unit. This could include continued demonstration of the unit at Coal Creek, making the unit available for installation and demonstration at a facility operated by another LRC member, or sale of the unit in order to make a partial refund to the LRC of grant monies.

Anticipated results

It is anticipated that completion of Step One (initial validation) will provide high level and conceptual confirmation of the viability of installing larger waste heat generators at lignite power plants. Should the study results indicate otherwise, the Step Two (demonstration) will not be pursued, minimizing the LRC's financial exposure.

Assuming that Step Two proceeds, it is anticipated to demonstrate the technical viability of generating electricity from waste heat sources at a lignite power plant, highlight any technical and practical issues with installation and running that may not have been anticipated at the feasibility stage, and provide a real life demonstration to attract the interest and support of other participants in the lignite industry.

Facilities, resources, and techniques to be used

Great River Energy has been very generous in allowing Calnetix to use its Coal Creek Station as a demonstration site, and the use and services of its engineers and other personnel. Charlie Bullinger will act as lead contact at GRE.

Calnetix will also use the services of HDR Engineering as engineering consultants on issues relating to waste heat capture from the plant and general installation issues. Dave Schmitz will act as lead contact at HDR.

Calnetix will also use its own internal engineers and business development personnel to work with GRE and HDR on the project. Calnetix personnel Gordon Foster (Business Development Manager), Shamim Imani (Director of Engineering) and Chuck Taylor (President of Application Engineering) will act as leads from Calnetix.

Environmental and economic impacts of the project while the project is underway

Any tie ins will be optimally planned to be done during planned plant shut-downs so that impact to plant operations will be minimal. There will be no disruption of the plant operations during the feasibility study and demonstration steps.

Ultimate technological and economic impacts

Based on the preliminary investigation conducted at Coal Creek, there is anticipated to be at least 200MW of extractable waste heat available for conversion to electricity at the Coal Creek Station. Assuming the net heat-to-electricity conversion rate of Calnetix's current WHG100 of 16%, an extra 32MW of electricity could theoretically be generated at Coal Creek. This would improve the overall efficiency of the plant by approximately 2.5%.

As noted above,[8] there are six Lignite Coal power plants in North Dakota that generate approximately 29.6m MWh of electricity annually. Calnetix believes that using its system, an extra 915,000 MWh of electricity could be generated from the waste heat at these plants without additional fuel costs or emissions penalties. A waste heat recovery unit may also contribute to North Dakota's RPS goals, and could also provide value (in the form of lower carbon costs per MWh) to utilities under the recently proposed Obama Administration cap and trade program.

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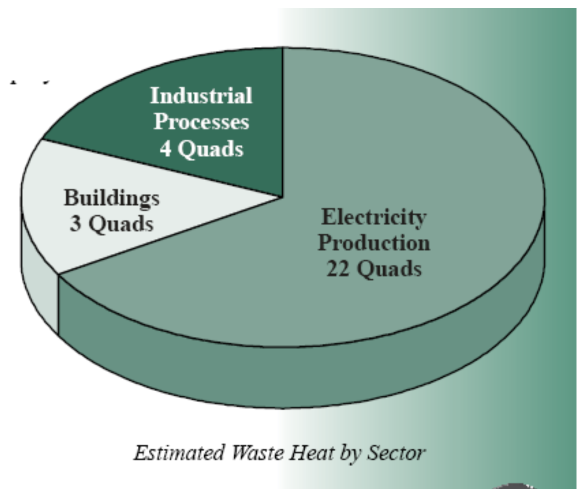
[8] See page 10 above.

On a national scale, the potential benefits of low temperature waste heat recovery are significant. According to the DOE, there is approximately 26 Quads or 8.5million GWh of recoverable waste heat per year available in the United States from thermal power plants and industrial processes.[9] The waste heat from thermal power plants exceeds the energy annually consumed by the U.S. transportation sector. [10] Assuming 20% of this waste heat was accessed at a net conversion rate of 16% would imply generation of approximately 272,000 GWh of electricity from recovery of this waste heat, equal to approximately 7% of US grid capacity.[11]



Waste Heat by Sector: DOE Thermally Activated Technologies, Technology Roadmap; May 2003

Producing sufficient Calnetix units to supply 10% of this potential market (250 1.5MWe units per year for 10 years) is estimated to create a North Dakota based business generating revenues of over $950m per annum and employing in excess of 500 workers.[12]

[9] DOE Thermally Activated Technologies, Technology Roadmap; May 2003.
[10] DOE Thermally Activated Technologies, Technology Roadmap; May 2003.
[11] US Grid capacity equal to approximately 4.16m GWh; Energy Information Administration – Electric Power Monthly, December 2008.
[12] Calnetix estimates based on current WHG100 costs and production staffing.

4. Standards of Success

Step One

Validating that there is a basic technical and economic feasibility/justification for using waste heat from a lignite power plant, and sufficient quantities of waste heat exist, to generate electricity using multiple Calnetix 1-2MWe organic rankine cycle waste heat recovery generators. Sufficient evidence that Calnetix should proceed with Step Two (site demonstration).

Step Two

Generation of reliable and consistent power from a waste heat source at GRE's Coal Creek Station with no fundamental technical issues. Basic economic validation of the application. Sufficient evidence that Calnetix should continue with development of a 1-2MWe unit.

5. **Background.**

Prior work related to the project conducted by the applicant and other participants includes:

(a) development of the Calnetix WHG100 waste heat generator;

(b) study and conceptual design of a 1.5MWe waste heat generator suitable for power plant applications;

(c) internal Calnetix study on the application of waste heat recovery to lignite power plants to assess market sizing and industry viability; and

(d) November 2008 site visit to Great River Energy's Coal Creek Station.

Development of Calnetix Waste Heat Generator:

Calnetix's WHG100 waste heat generator was developed as an efficient means of converting waste heat as low as 200F into electricity. Figure 1 illustrates the workings of the unit (numbers correspond to the descriptions below):

1. The unit employs an organic rankine cycle closed loop in which R245fa (non-flammable, biodegradable refrigerant manufactured by Honeywell) is exposed to the waste heat source and changes from liquid to superheated gas.
2. This pressurized gas is used to spin a turbine wheel coupled to a high speed generator spinning between 20,000 – 30,000 rpm, producing electricity.
3. After exiting the turbine, the gas is passed through an economizer where a portion of its heat is stripped out and used to pre-heat the liquid refrigerant at another point of the cycle (see step 5 below).
4. The gas is routed through a condenser to lower its temperature and return it to its liquid state.

5. To increase system efficiency, the liquid refrigerant is routed to an economizer (exposing it to the gasified refrigerant exiting the turbine), increasing its temperature before re-exposing it to the waste heat source, re-gasifying it and repeating the cycle.

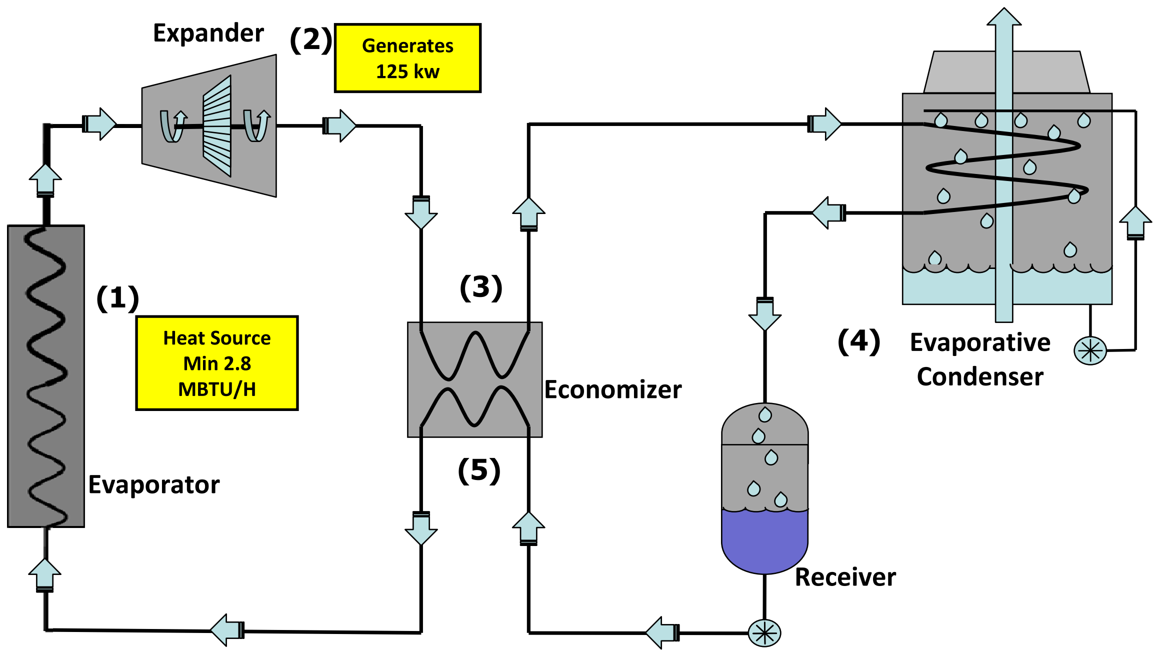


Figure 1: Calnetix WHG100 Cycle

Under standard conditions, the WHG100 can utilize 625-700kW of heat input to generate 100-110kWe net electricity. This net output typically varies in this range based on environmental conditions and installation configuration.

The heart of the Calnetix unit is the integrated expander/generator module. The module is comprised of a turbo expander, high speed permanent magnet generator, magnetic bearing system, and housing with turbo nozzle cone. Figure 2 below shows a cutaway of the module. The module is designed so the refrigerant flows through the unit (from right to left in the figure). The refrigerant flows around the turbo nozzle cone and is expanded over the turbine impeller, which together with the resulting pressure drop through the expander, causes the turbine and directly coupled generator to spin up to 30,000 rpm. The generator is directly exposed to the expanded refrigerant for cooling before it exits through the outlet. The benefit of this design is that the generator does not require its own cooling system with a pump to circulate coolant, thereby optimizing the efficiency of the system. The magnetic bearings also contribute to system efficiency as there is no contact and thus no friction between the rotating component and the bearings. At such high rotational speed, conventional bearings would require frequent maintenance and replacement due to contact wear.

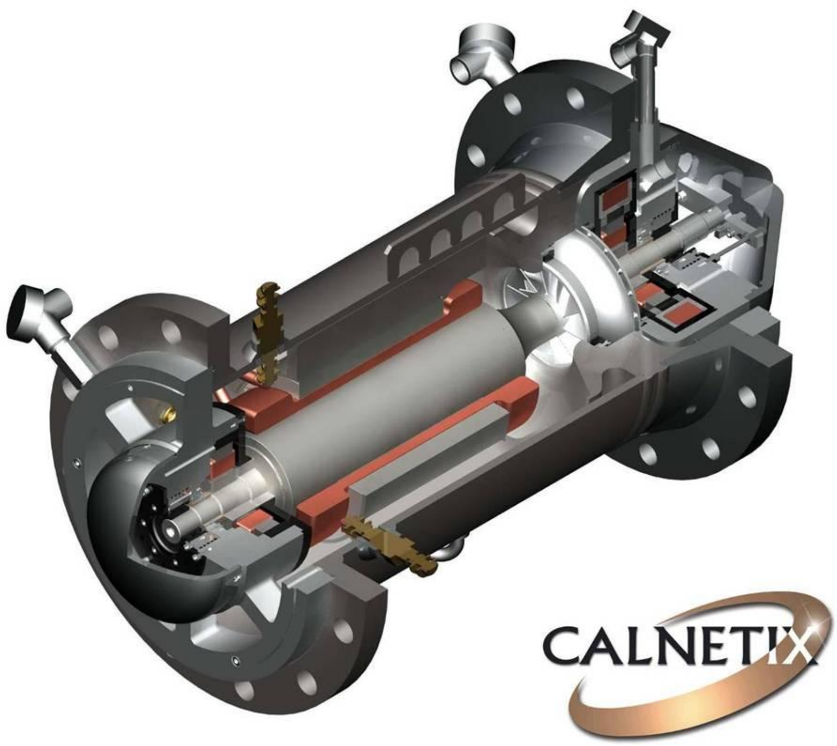


Figure 2 Calnetix Integrated Expander/Generator Module

Calnetix utilizes a smart high switching frequency rectifier and inverter system to convert the energy of the generator to grid voltage and frequency. The Calnetix smart rectifier/inverter system is able to compensate for the varied speed of the generator based on varying waste heat load conditions, thus always enabling the system to run at its most efficient point. Competitor products can only run at a fixed speed and employ a gearbox between the turbine and generator, resulting in a less efficient system due to the lack of speed optimization capability and the losses of the gearbox.

Figure 3 shows the WHG100 as manufactured at the Calnetix production facility. The unit includes all functionality necessary outside of the heat exchanger and condenser.

Figure 3 Calnetix WHG100

Figure 4 shows a standard 'packaged' unit (i.e. 20-ft container into which the WHG 100 has been fitted) in a typical application. Here, methane from a waste water treatment facility is being combusted and the heat energy is converted to electricity. On top of the container is the combustor along with the heat exchanger that exchanges the combusted exhaust gas with the refrigerant. Behind the container (to the right in the bottom photo) is the evaporative condenser.

Figure 4 Application of Calnetix WHG100 waste heat recovery generator

The packaged unit pictured above is the same type of unit that would be installed at Coal Creek for the Step Two demonstration, and the Coal Creek installation would likely have a similar configuration and layout.

The primary advantage of the WHG100, and Calnetix's design and manufacturing approach, is its 'modular' design and factory based production. This allows a standardized product with resultant cost and quality advantages, as well as pre-packaged as a 'plug-and-play' unit requiring only the installation of heat exchanger and condensing source, and connection to the grid. Other commercially available waste heat recovery units are custom designed for each installation, which involves considerable time and costs related to custom engineering.

The WHG100 has also been designed to be matched to varying applications including different heat sources (liquid or gaseous), or different condensers manufactured by third parties (air or water cooled). Combining a standardized product to existing third part components also allows for overall reduction in installation costs and lead times.

<u>Study and Conceptual Design of a Larger Unit</u>

The current Calnetix unit can be installed in parallel (i.e. units packaged together using common piping and controls and utilizing a single heat exchanger and condenser) to extract heat sources that are over the capacity of one unit. However, due to space and other factors such as pressure drop within piping, it is not feasible to parallel more than about five units. In addition, many heat sources from power plants and large industrial facilities would support multi-MW installations.

In order to extract larger waste heat sources within power plants and larger industrial applications more efficiently, as well as address larger industrial and utility waste heat sources without paralleling dozens of smaller units, Calnetix believes it is optimal to develop a larger unit in the 1 to 2 MWe range.

The current low temperature ORC solutions in this power range are all custom built and installed using fixed speed or geared generators, which results in large, expensive and relatively inefficient installations. Calnetix believes that at this larger power range, there is significant advantage in keeping the same high speed, modular, factory built 'plug and play' design philosophy as the current WHG100 production unit, in order to reduce the engineering cost and lead time necessary for on-site application to the various waste heat sources.

Calnetix has undertaken conceptual design and engineering work on this larger unit, including preliminary analysis of:

- ORC cycle analysis and refrigerant
- Usable temperature ranges
- Power output
- Expander and generator design and specification
- Heat exchanger and condenser specifications
- Development timeline
- Cost + ROI/Payback

A schematic of the conceptual design from this work is set forth below. This design would be used as the basis for the physical development of the large unit, for which Calnetix is seeking funding from the DOE.

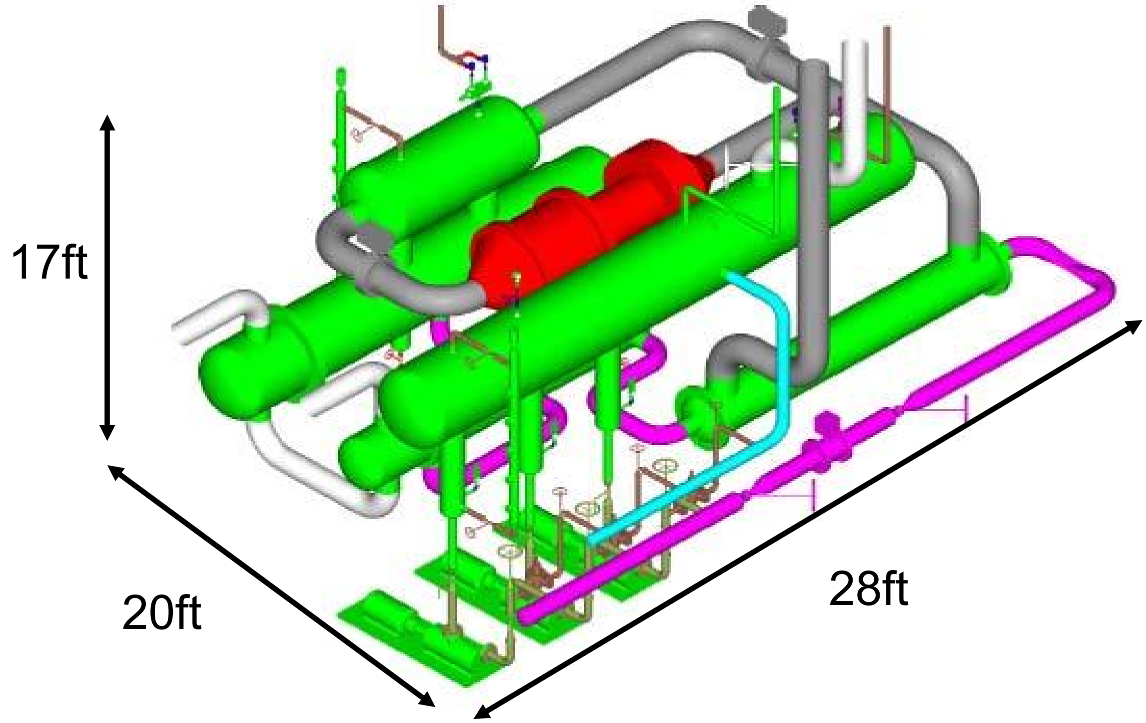


Figure 5. Conceptual Design of 1.5MW Calnetix Waste Heat Recovery Unit

<u>Internal Calnetix Study On The Application Of Waste Heat Recovery To Lignite Power Plants</u>

Calnetix estimates that lignite power plants in North Dakota could potentially generate an additional 915GWh of emissions-free electricity by recovering low-grade waste heat. This translates into a 3% improvement in overall efficiency. This figure assumes that the average lignite power plant is 33% efficient and that of the remaining 67% wasted energy, 10% of this is recoverable waste heat which can be converted into electricity at 16% net efficiency. The table below lists the major lignite plants in the North Dakota, along with estimated output, efficiency, and recoverable waste heat. A more detailed study will be required to refine these estimates.

Potential Waste Heat at North Dakota Lignite Coal Plants

Power Plant	Net Generation (MWh) (1)	Assumed % Efficiency	Waste Energy (MWh)	Extractable Waste Heat % of waste energy	Extractable Waste Heat MWh	ORC Potential (MWh) (2)
Antelope Valley Station	6,317,269	33%	12,825,970	10%	1,282,597	205,216
Coyote Station	3,060,200	33%	6,213,133	10%	621,313	99,410
Leland Olds Station	4,576,988	33%	9,292,673	10%	929,267	148,683
Milton R. Young Station	5,117,272	33%	10,389,613	10%	1,038,961	166,234
Coal Creek Station	8,559,089	33%	17,377,544	10%	1,737,754	278,041
Heskett Station	523,027	33%	1,061,903	10%	106,190	16,990
Total	28,153,845		57,160,837		5,716,084	914,573

(1) CEC, North American Power Plant Air Emissions, 2004
(2) Assumes 16% ORC efficiency

The improvement in efficiency would have both economic and environmental benefits. Generation of electricity from waste heat, and the net efficiency gains from it, could be used to generate the same amount of electricity using less fuel, or more electricity for the same fuel input. Either way, there would be an economic and emissions benefit from using less fuel to generate a given amount of electricity. Calnetix estimates that using waste heat generation, and maintaining current power output, lignite plants in North Dakota could collectively reduce CO2 emissions by 1,200,000 tons per year as well as meaningfully reduce emissions of SO2, NOx, and Mercury. The table below lists the emissions profile of each lignite plant and the potential emissions benefit of waste heat recovery at current power outputs.

Potential Emissions Savings from Waste Heat Recovery

Power Plant	ORC Potential (MWh)	Emissions (lbs/MWh) (1) CO2	SO2	Nox	Mercury	Annual Savings (tons) CO2	SO2	Nox	Mercury
Antelope Valley Station	205,216	2,447.2	4.1	4.1	63.7	251,100	419	425	6,535
Coyote Station	99,410	2,572.1	8.1	7.9	98.5	127,845	401	395	4,895
Leland Olds Station	148,683	2,462.9	20.5	4.8	70.6	183,094	1,524	359	5,248
Milton R. Young Station	166,234	2,411.8	11.1	9.0	98.1	200,463	919	750	8,153
Coal Creek Station	278,041	2,640.5	7.6	3.0	98.6	367,083	1,062	413	13,705
Heskett Station	16,990	2,500.0	5.0	5.0	90.0	21,238	42	42	765
Total	914,573	2,505.7	9.4	5.7	86.6	1,150,823	4,368	2,384	39,300

(1) Emissions data from EPA emissions tracking system; Calnetix estimates used for Heskeet Station

There are two main economic benefits. The first benefit relates to cost savings from lower coal usage, with savings estimated at $20/MWh. This represents the estimated marginal cost of power generation (i.e., before distribution and transmission costs). The second benefit relates to potential cost savings from a future carbon credit trading system. The Obama Administration is proposing a plan that would require US industries to buy a carbon credit (equal to one ton of CO2 emitted) for every ton of emissions. Point Carbon, an industry research group, has estimated that the Obama plan would cover 80% of US businesses and result in a price of $13-$20 per ton of CO2.[13] For power plant operators in North Dakota, this would translate into hundreds of millions of dollars of additional cost.

Calnetix estimates that through utilizing waste heat recovery, North Dakota's lignite plants could save close to $35 million per year from lower coal usage and lower carbon emissions. This is estimated on fuel savings alone and does not take into account the avoided capital cost from creating new coal fired capacity at a potentially higher cost per kWh than a waste heat solution. The analysis is shown in the table below.

Potential Economic Benefit

Power Plant	ORC Potential (MWh)	Efficiency Gains		CO2 Savings			Total
		Cost/kWh	Savings/yr ($)	$/Carbon credit	Emission (tons)	Savings/yr ($)	Savings ($)
Antelope Valley Station	205,216	0.020	4,104,311	13.70	251,100	3,440,074	7,544,385
Coyote Station	99,410	0.020	1,988,203	13.70	127,845	1,751,470	3,739,672
Leland Olds Station	148,683	0.020	2,973,655	13.70	183,094	2,508,383	5,482,038
Milton R. Young Station	166,234	0.020	3,324,676	13.70	200,463	2,746,342	6,071,018
Coal Creek Station	278,041	0.020	5,560,814	13.70	367,083	5,029,043	10,589,858
Heskett Station	16,990	0.020	339,809	13.70	21,238	290,962	630,771
Total	914,573		18,291,468		1,150,823	15,766,273	34,057,741

[13] For above purposes, Calnetix has used $13.70/ton, the price assumed by Point Carbon as the cost per ton of CO2 emissions in 2012 under the Obama Administration February 2009 cap and trade proposal.

Site Visit to GRE's Coal Creek Station

Set out below is a summary of the tour taken of Coal Creek Station in Underwood, North Dakota, mid November 2008, by representatives of Calnetix. Calnetix was hosted by Charlie Bullinger from GRE.

Coal Creek was commissioned in 1979-80 and is owned and operated by Great River Energy. The plant has a total generation capacity of 1,200MW and consumes approximately 22,000 tons of lignite coal per day. Set out below are the summary findings from the visit as they apply to a potential waste heat recovery application.

1. **Soot blower drain:** Steam to clean the lining of the boiler system is more important to lignite plants versus other coal plants and significant steam drain is available at over 400ºF with about 15,000lb/hr for 600MW plant. This could be converted to electric power.

2. **Flue gas:** Assuming power plant efficiency of around 30%, 30% of the input energy is dissipated through the chimney. The flue gas temperature is around 350ºF with a flow of about 1.8M acfm. This waste heat is being cooled down in a wet scrubber system to 170ºF. At Coal Creek, a Calnetix waste heat recovery system could potentially capture about 60MW of electric power from this heat source. A closer study will be conducted to identify the challenges of installing heat exchangers to this heat source.

3. **Fly-ash:** Fly ash is collected after the high temperature firing point in the boiler and mixed with some type of liquid to transfer. The temperature of the fly ash is above 300ºF. This could be a great heat source for a Calnetix waste heat generator.

4. **Other:** Scrubber sludge has also been identified as a possible source of heat. Although the temperature is around 200ºF or lower, this heat can be utilized as a pre-warmer of the organic fluid.

6. Qualifications

Calnetix

Established in 1998, Calnetix Inc (www.calnetix.com) designs, manufactures, and markets innovative power generation products that help customers save energy and money. Calnetix is headquartered in Southern California with manufacturing facilities in California and Florida. Calnetix has a global OEM customer base including Shell, Honeywell, British Petroleum and Mitsubishi Heavy Industries.

Calnetix's core technologies include high speed permanent magnet motors and generators, magnetic bearings, power electronics, turbines and expanders used to develop solutions for customers including end-use solutions such as microturbines and waste heat recovery units. Calnetix has an experienced management team with over 100 years of combined experience relevant to waste heat and gas opportunities. Calnetix owns 100% of its key IP, including trade secrets, manufacturing processes, and 12 patents.

Applicant Representative: Gordon Foster (Business Development Manager)

Gordon has over eight years experience in business development related to the energy and alternative energy industry. He holds a Masters of Business Administration degree from the Anderson School of Management (UCLA) and a Masters of Science as well as Bachelors of Science degree in Mechanical Engineering from Texas Tech University in Lubbock, Texas.

Principal Investigator: Shamim Imani (Director of Engineering)

Shamim has over 10 years of experience in the industry developing energy related products. He has worked extensively with and led many developments including flywheel systems, turbo chargers (automotive and marine), expanders, compressors and microturbines. He holds a Masters of Science in Electrical Engineering from University of California, Los Angeles (UCLA) and a Bachelors of Science degree in Electrical Engineering from California State Polytechnic University, Pomona (CalPoly, Pomona) and has published numerous technical papers.

Chuck Taylor (President of Application Engineering)

Chuck has over 30 years experience in Industrial Refrigeration both on the contracting side and on the engineering side. He has a Bachelors Degree in Mechanical Engineering, a Master's Degree in Business Administration and is licensed as a professional engineer in 38 states.

Prior to joining Calnetix, Chuck founded and ran his own refrigeration engineering firm CRT Design. Prior to CRT, he spent 20 years with The Stellar Group in Jacksonville, Florida, Under Chuck's leadership, Stellar refrigeration doubled in size to become the largest industrial refrigeration Design/Build firm in the U.S.

Great River Energy

Great River Energy (www.greatriverenergy.com) is a generation and transmission (G&T) cooperative that provides wholesale electric service to 28 distribution co-ops that serve more than 620,000 members. It owns more than 4,500 miles of transmission power lines and owns or co-owns more than 100 transmission substations in Minnesota, North Dakota and Wisconsin.

Charlie Bullinger (Senior Principal Engineer)

Charlie has been with Great River Energy since 1977, currently holding the position of Senior Principal Engineer in Dry Fining, Marketing, and EPRI R&D. He is a Professional Engineer registered in both the State of North Dakota as well as the State of Minnesota. Charlie holds a Bachelors of Science degree in Mechanical Engineering from the North Dakota State University.

Richard Garmin (Engineering Project Manager)

Rich possesses eighteen years of Utility Experience. He is currently Engineering Project Manger for approximately $500M in projects centered in Central North Dakota, currently focused on a $150M Scrubber installation project as well as a $150M turbine generator project at the Stanton Station. Prior to GRE, Rich worked at PacifiCorp's Wyodak plant as a Lead Maintenance Engineer. He holds a Masters of Business Administration and Project Management degree from the University of Mary, and a Bachelors of Science degree in Mechanical Engineering from the South Dakota School of Mines & Technology.

HDR

HDR (www.hdrinc.com) is an employee-owned architectural, engineering and consulting firm that helps clients manage complex projects and make sound decisions. HDR has more than 900 staff dedicated to Power and energy projects. HDR has helped design and construct efficient and economical power plants for more than 90 years. As a leader in renewable power industry, HDR has been involved with the development of more than 16,000 MW of wind energy.

Roger W. Nagel, P.E.

Roger possesses over seventeen years of experience in the development and design of power generation and cogeneration projects. He has been involved with the design of combined cycle and conventional steam plants fueled with gas, gasified LNG, oil, coal, pond fines, landfill gas and petroleum coke. Experience includes involvement with feasibility studies, proforma analyses, thermal cycle design, system design, equipment specification and technical equipment contract administration.

David P. Schmitz, P.E. Regional Power Program Manager

David has over 35 years of experience with Basin Electric Power Cooperative where his roles included plant engineer, project engineer, project coordinator, project manager, manager of engineering, and VP of engineering and construction. Experience includes operations, engineering and construction of large lignite and PRB fueled power plants, engineering and construction of high voltage transmission lines and substations, and combustion turbine units, planning and expansion of microwave and fiber optic telecommunications systems and key roles in acquisition and subsequent modifications to the Great Plains Synfuels plant. His most recent project was working on the development of a new large base load power plant with primary emphasis on site and technology selection (especially IGCC vs SCPC and carbon capture) and development of a permitting strategy.

7. Value to North Dakota.

Assuming the project is fully funded, Calnetix anticipates that the results of the demonstration will show technical viability of, and market opportunity for, low temperature waste heat recovery at lignite power plants. These results will be vital in allowing Calnetix to further develop and commercialize its larger unit. They could also be used by the lignite industry to show an economically feasible way of improving plant efficiency and decreasing net emissions.

Based on the preliminary investigation conducted at Coal Creek, Calnetix estimates that at least 200MW of extractable waste heat is available for conversion to electricity at the plant. Assuming the same net heat-to-electricity conversion rate of 16% of Calnetix's current 100kWe unit, which should be able to be replicated in the larger unit, an extra 32MW of electricity could potentially be generated at Coal Creek by installing the larger waste heat units. This would improve the overall efficiency of the plant by approximately 2.5%.

As set out above, there are six Lignite Coal power plants in North Dakota, which Calnetix estimates could derive an additional 915,000 MWh of electricity from installation of waste heat units without additional fuel costs or emissions penalties.[14]

A waste heat recovery unit may also contribute to the North Dakota RPS objectives, and provide potential cost savings under the Obama Administration's recently introduced carbon cap and trade proposal. At an estimated cost of $13.70/ton of CO2, utilization of waste heat recovery on lignite power plants in North Dakota could provide a saving of approximately $16m/year under this proposal.[15]

[14] See page 10 above.
[15] See page 10 above.

Calnetix believes the above efficiency and savings benefits could assist in keeping lignite coal economical and competitive as a fuel source into the future.

Calnetix also intends to produce the larger waste heat unit in North Dakota, and estimates that (subject to funding) initial commercial production units should be commercially available within 36 months. As noted above, Calnetix calculates that approximately 272,000 GWh could be generated annually from waste heat sources from thermal power plants and industrial processes in the US alone.[16] Producing sufficient Calnetix units to supply 10% of this potential market (250 1.5MWe units per year for 10 years) is estimated to create a North Dakota based business generating revenues of over $950m per annum and employing in excess of 500 workers.[17]

[16] See page 16 above.
[17] Calnetix estimates based on current WHG100 costs and production staffing.

8. Management.

Calnetix will assign a project manager to ensure that tasks are carried out on schedule, and that the objectives set forth herein will be met within the 22 months allotted. This project manager will coordinate activities by HDR Engineering, Great River Energy, as well as those activities internal to Calnetix. The project manager will also monitor the budget for the program to ensure against overruns.

As detailed in Section 3 (Project Description), Step One entails a sixteen week process to identify and quantify heat sources, and validate the technical viability of connecting the Calnetix unit to these sources. This step primarily involves the project manager coordinating with HDR Engineering to ensure execution on the specific tasks as outlined below.

- Site visit to obtain data, review concepts and review existing plant equipment for potential utilization.
- Performance modeling of the existing facility before and after the addition of the WHG installation assuming 1 to 2 MW.
- Identification of technical risks and risk mitigation strategies.
- Development of cost estimate for total installation, including all equipment modifications and generator pricing as predicted by Calnetix.
- Development of a high level conceptual one-line diagram to represent the requirements for the electrical tie-in for new generation.
- Development of a feasibility study report describing the proposed installation and including the results of all of the above activities.

Within Step One, there are four evaluation points (monthly review meetings to track progress). These will be led by the project manager who shall ensure that appropriate milestones are being met. During these reviews, any necessary adjustments will be made to the tasks, especially as the tasks identified may not occur sequentially. It will also be the task of the project manager to ensure the feasibility study report is issued on time as the report will be the basis of proceeding with Step Two.

Waste Heat Recovery for Lignite Coal Fired Plants Step 1 - Identification & Validation

2009	Responsibility	Start	Due	Completed on	Issues
Step 1 Identification and Validation					
Kick-off meeting	All	2-Jun	2-Jun		
Site visit to Coal Creek to obtain data	All	3-Jun	3-Jun		
Review meeting 1	All	27-Jul	27-Jul		
Review meeting 2	All	28-Sep	28-Sep		
Facility and WHR Performance Modeling	Calnetix	8-Jun	12-Jul		
	HDR	8-Jun	12-Jul		
Risk Identification	HDR	15-Jun	28-Jun		
Process Flow diagrams	HDR	13-Jul	23-Aug		
Cost Estimate	Calnetix	17-Aug	17-Sep		
Progress Report	Calnetix	3-Aug	7-Aug		
Interim Report (to wrap up Step 1)	Calnetix	5-Oct	16-Oct		

Step Two involves installing and running the 100kWe Calnetix demo unit for proof of concept. This will involve coordinating the installation of the unit onsite, followed by continued monitoring of the unit once operational.

Regarding installation, the Calnetix project manager will coordinate with HDR, GRE and internal Calnetix engineers to develop an installation and site construction plan and schedule. Appointment of subcontractors shall be made in consultation with GRE and it is anticipated that installation progress will be monitored by GRE with frequent site visits by Calnetix personnel during this period.

During the testing phase, the unit will be continuously monitored in real time by Calnetix from its facility in Florida (the unit will have its own IP address and can download data in real time onsite). This information will also be available to GRE and HDR. If necessary, review meetings will be called.

Maintenance on the unit during the testing phase will be carried out by Calnetix or one of its authorized distributors in accordance with the prescribed maintenance schedules for the WHG 100.

Quarterly reports on unit performance, as well as the final report, will be prepared by Calnetix and distributed among the parties including the LRC according to the checklist and timetable below.

Waste Heat Recovery for Lignite Coal Fired Plants Step 2 - Calnetix demo

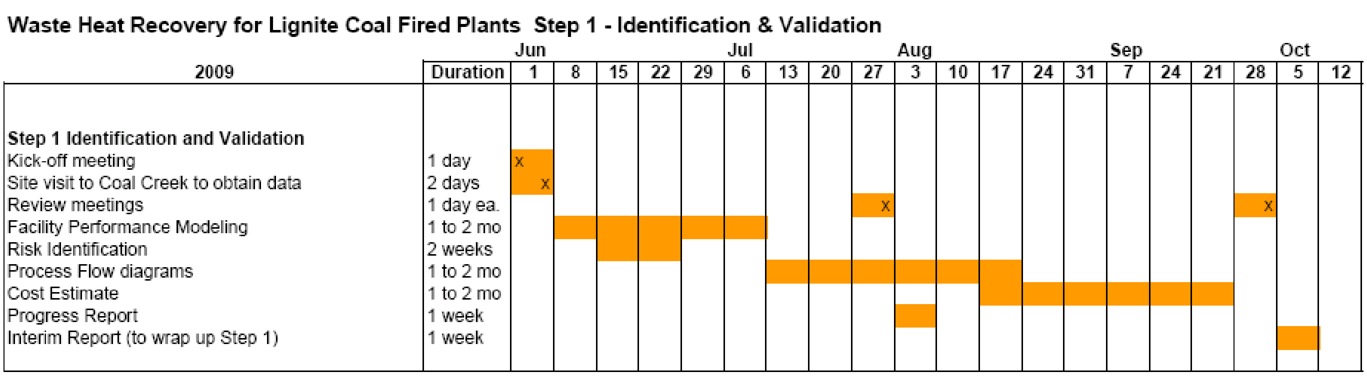
Months	Responsibility	Start	Due	Completed on	Issues
Step 2 Demonstration					
Order 100kW unit, heat exchangers, and misc.	Calnetix				
Calnetix components		1-Nov-09	15-Dec-09		
Ship to Coal Creek		15-Dec-09	4-Jan-10		
Vendor parts (drop ship)		1-Nov-09	4-Jan-10		
Install onsite (specifics tbd)	All	4-Jan-10	26-Feb-10		
Test period for 12 months	Calnetix, GRE	1-Jun-09	1-Jun-09		
maintenance (timing tbd)		TBD	TBD		
Interim reports					
Report 1	Calnetix	1-Jun-10	30-Jun-10		
Report 2	Calnetix	1-Sep-10	30-Sep-10		
Report 3	Calnetix	1-Dec-10	24-Dec-10		
Report 4	Calnetix	1-Mar-11	31-Mar-11		
Final Report	Calnetix	1-Mar-11	29-Apr-11		

9. Timetable.

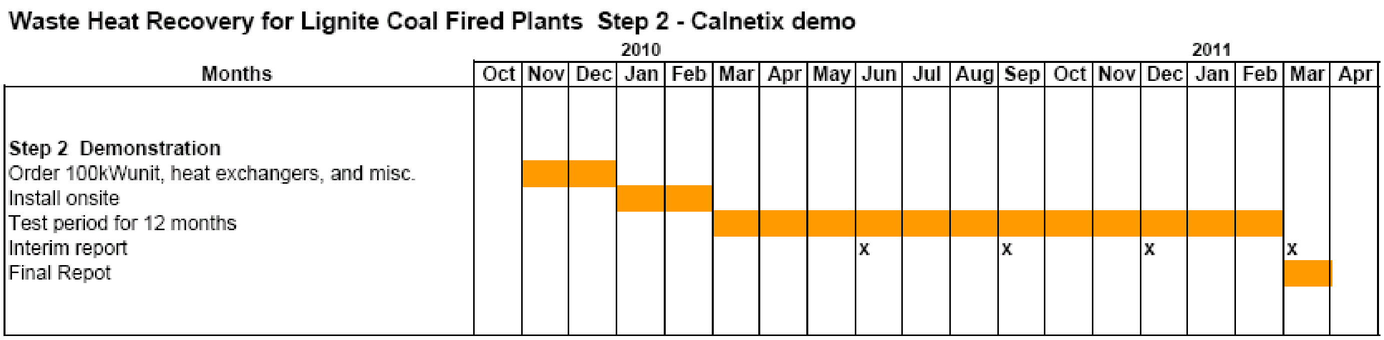
The proposed timeline for the project is set forth below. The project is divided into two steps and is based on the assumption that LRC funding will be made available by the end of May 2009 in order to commence the project by June 1.

Step One involves the identification and validation of waste heat sources. The details regarding the steps can be found in the Project Description section above. The projected timeline is 16 weeks thereby placing the completion date at the end of September.

Two months into Step One, a report will be submitted to track the progress of the study including an update on any foreseeable changes in the future timeline. At the end of Step One, an interim report will be submitted with the study results and, should study results support proceeding to the next phase, a request to fund Step Two. Should the study results not support proceeding with the demo, the report submitted at the end of September will be the final report.



Step Two involves the demonstration of the Calnetix WHG100 demo unit. The unit will be run for 12 months continuously in order to validate the concept. The schedule is based on the assumption that funds from the DOE will be made available by November 1, allowing Calnetix to start on the activity. Once funding is available, equipment will be purchased with an expected lead time of two months for receipt. Once the equipment is received, it is anticipated the installation process will take another two months. Based on this timeline, the demonstration can start functioning by the beginning of March 2010. During the 12 month demonstration period, each quarter a progress report will be submitted, followed by a final report that will be generated based on the data gathered throughout those twelve months.



Following completion of the demonstration (i.e. after 12 months), Calnetix and GRE, in consultation with the LRC, will make a determination of the ongoing use of the unit. This could include continued demonstration of the unit at Coal Creek, making the unit available for installation and demonstration at a facility operated by another LRC member, or sale of the unit in order to make a partial refund to the LRC of grant monies.

10. Budget

The budget for Step One is a combination of a 'not to exceed' estimate of $80,000 for engineering consulting services provided to Calnetix by HDR Engineering, direct costs incurred by Calnetix in supporting the project and providing engineering services for design and installation of a potential large unit, and in kind contributions from GRE of salaried personnel who will be spending time and resources on the project. The budget uses a standard engineering hourly rate of $165/hour for Calnetix and GRE resources.

A breakdown of these costs in relation to Step One is as follows:

Waste Heat Recovery for Lignite Power Plants Step One - Identification & Validation						
2009	**Responsibility**	**Resource**	**Hours**	**In-kind**	**Direct Cost**	**Duration**
Kick-off meeting	Calnetix	2	10		$1,650	1 day
	GRE	2	10	$1,650		
	HDR				fixed	
Site visit to Coal Creek to obtain data	Calnetix	3	20		$3,300	2 days
	GRE	2	20	$3,300		
	HDR				fixed	
Review meetings	Calnetix	2	20		$3,300	1 day ea.
	GRE	2	20	$3,300		
	HDR				fixed	
Facility and WHR Performance Modeling	Calnetix		50		$8,250	1 to 2 mo
	HDR				fixed	
Risk Identification	HDR				fixed	2 weeks
Process Flow diagrams	HDR				fixed	1 to 2 mo
Cost Estimate	Calnetix		50		$8,250	1 to 2 mo
	HDR				fixed	
Progress Report	Calnetix		20		$3,300	7-Aug
	HDR				fixed	
Interim Report (to wrap up Step 1)	Calnetix		30		$4,950	16-Oct
Administration (including travel etc)	Calnetix				$20,000	
	GRE			$20,000		
	HDR				fixed	
	Total in-kind		50	$28,250		
	Total Direct (includes HDR not to exceed $80,000)				$133,000	
	Grand Total				**$161,250**	

The budget for Step two is a combination of hardware/equipment costs, onsite installation costs and additional engineering from HDR and contributions from Calnetix and GRE, using the same assumptions regarding Calnetix and GRE hourly costs as Step One.

A breakdown of Step Two costs is as follows:

Waste Heat Recovery for Lignite Coal Fired Plants Step Two - Demonstration					
	Responsibility	**Hours**	**In-kind**	**Direct Cost**	**Duration**
Step 2 Demonstration					
Install 100kW unit, heat exchangers onsite	Calnetix			$501,195	4 mo
Test period for 12 months	GRE	520	$85,800		Monitor 2 hours per day
	Calnetix	520		$85,800	Monitor 2 hours per day
Interim reports	Calnetix	80		$13,200	4 reports
Final Report	Calnetix	40		$6,600	29-Apr
Administration	Calnetix GRE	100 160	 $26,400	$16,500	
	Total in-kind Total Direct Cost **Grand Total**		$112,200	 $623,295 **$735,495**	

The requested Step One grant of $80,000 will primarily support the costs of HDR Engineering, and Calnetix and GRE will meet their own costs. The requested Step Two grant of (not to exceed) $250,000 will pay a portion of the capital equipment costs related to the demonstration alongside matching funds from the Department of Energy.

The funding requested is necessary to achieve the project's objectives as without LRC support, it is unlikely that Calnetix would seek to undertake performance modeling of its unit, or undertake demonstration testing, at a lignite power plant. In addition, without LRC support, Calnetix anticipates that commercialization of the larger unit would be delayed and may potentially not be designed in a form suitable for installation at thermal power plants.

11. Matching funds

At Step One, Calnetix has obtained a 'not to exceed' quote of $80,000 from HDR Engineering as part of an overall estimated cost of $161,250. The remaining funds will be provided by the direct resources of Calnetix (engineering and administration), and in kind resources of GRE (engineering, plant access and administration) who shall be involved in the project on a day to day basis. Assigning these personnel to this project represents out of pocket and opportunity costs for Calnetix and GRE. If, for any reason, the overall costs of the project (including expenses of HDR Engineering) are greater than the estimated $161,250 set forth in this application, Calnetix will pay the difference directly in order to ensure that this step is completed.

At Step Two, matching funds will be provided by the DOE funding currently being sought by Calnetix, as well as further direct resources provided by Calnetix and in kind contributions from GRE. In addition, Calnetix shall apply 'most favored nation' pricing to the WHG100 demonstration unit to be installed onsite, such that if the unit is being supplied to another customer of Calnetix at a price less than that set forth in this application such price shall also be applied when supplying that unit to the project.

12. Tax Liability Affidavit

CERTIFICATE OF THE CHIEF FINANCIAL OFFICER OF CALNETIX, INC.

Ian Hart hereby certifies that he is the duly authorized Chief Financial Officer of Calnetix, Inc., a California corporation (the "Company"), and further certifies that:

1. The Company has timely filed all federal and California tax returns required by law (or has timely filed an appropriate extension therefor) and, to the knowledge of the undersigned, has paid all taxes, assessments, interest and penalties owing to applicable tax authorities. The Company has received no notice of the revocation of its authority to do business. The Company does not have an outstanding tax liability owed to the State of North Dakota or any of its political subdivisions.

2. The statements contained or referred to herein are true and correct and do not set forth facts which are false or misleading nor do they omit to set forth facts the absence of which would make such statements false or misleading.

Dated: March 18, 2009

Calnetix, Inc.

Ian Hart CFO

Ian Hart, Chief Financial Officer

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13. Confidential Information.

N/A