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March 21, 2012

North Dakota Industrial Commission
State Capitol - 14th Floor
600 East Boulevard Ave. - Dept 405
Bismarck, ND 58505-0840
Attn: Lignite Research Program

**Subject: North Dakota Industrial Commission – Grant Request Transmittal Letter**

Please accept this grant request to fund a lignite research project. The proposed project addresses several of the Commission's research priorities, as described in the attachments. We understand that the next step will involve Lignite Research Council (LRC) technical review. If approved, a contractual commitment will follow within 60 days, between the Commission and the Grantee.

If you have questions about the contract or our participation in this project, please call Greg Archer at 763-445-5206 or Charlie Bullinger at 701-442-7662.

Sincerely,

GREAT RIVER ENERGY

Rick Lancaster
Vice President, Generation

Encl.

C: Greg Archer - GRE
Charlie Bullinger - GRE
Ramsay Chang - EPRI
Diane Stockdill - GRE

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GREAT RIVER ENERGY

12300 ELM CREEK BLVD.
MAPLE GROVE, MN 55369

56-382
412

WELLS FARGO BANK, N.A.
115 Hospital Drive
Van Wert, OH 45891

CHECK NO. 476857

DATE 03/15/12

PAY ONE HUNDRED AND 00/100------------------------------------------------

AMOUNT

$ ********100.00

U.S. DOLLARS

PAY TO THE ORDER OF
ND INDUSTRIAL COMMISSION
STATE CAPITAL 14TH FL
600 E BLVD AVE DEPT 405
BISMARCK ND 58505-0840

VOID AFTER 6 MONTHS

SECURITY FEATURES INCLUDED. DETAILS ON BACK.

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VENDOR # 7501 VENDOR NAME ND INDUSTRIAL COMMISSION DATE 03/15/12 CHECK NO. 476857

| INVOICE NUMBER | DATE | P.O. NO. | GROSS AMT. | DISCOUNT | NET |
|---|---|---|---|---|---|
| LRP GRANT FEE<br>ATTN: LIGNITE RESEARCH PROGRAM | 03/12/12 | | 100.00 | 0.00 | 100.00 |
| | | TOTALS | 100.00 | 0.00 | 100.00 |

CURRENCY: U.S. DOLLARS

# Novel In-situ Sorbent Activation Process (SAP) – An evaluation of North Dakota lignite and lignite by-product feasibility to reduce mercury in exhaust gases over an extended period

Applicant

**Great River Energy**

Principal Investigators

**Greg Archer, Charlie Bullinger,**

**Ramsay Chang and Diane Stockdill**

Date of Application

**March 21, 2012**

Amount of Request

**$400K, or <50 percent of the overall estimated project budget**

## Table of Contents

## Figures

# 1.0 Abstract


## 1.1 Objective

With the US Environmental Protection Agency's issuance of the final Mercury and Air Toxics Standards (MATS), it is clear that utilities are faced with making significant mercury reductions (among other pollutants) in a relatively short timeframe. Great River Energy has spent over 10 years evaluating various mercury reduction technologies, and has generally determined that commercially available, activated carbon provides the most cost-effective, technologically availably, option at this time. Given that there are currently no commercial carbon vendors in North Dakota, there are both supply chain and cost risks associated with reliance on an out-of-state vendor for this critical compliance feedstock.

Consequently, the Electric Power Research Institute (EPRI) and the Illinois Prairie Research Institute at the University of Illinois at Urbana-Champaign (UIUC) have developed a patented technology for the on-site production of activated carbon (AC). This technology, the Sorbent Activation Process (SAP), is projected to reduce the cost of activated carbon for mercury control by >50 percent. SAP involves the on-site production of AC from coal which is then injected directly into the flue gas upstream of a particulate control device, such as an existing electrostatic precipitator (ESP) or baghouse, to capture mercury in flue gas. The process makes use of the concept of rapid gasification (one to two seconds) of fine pulverized feed coal in a long tubular reaction chamber which forms activated carbon. Chemical additives such as bromides and steam are added to the mixture to enhance the reaction. For some applications, the SAP products may be processed through a cyclone collector where the activated carbon is collected and then injected into the flue gas while the product gas (containing residual CO) is recycled to the boiler. The feedstock coal used can be the same coal burned by the utility. SAP can be used to prepare ACs with various surface areas, pore structures, and surface chemistry from bituminous, sub-bituminous, and lignite coals. To date, SAP has been tested for short durations at commercial scale with sub-bituminous and bituminous coals, at Dynegy Midwest Generation's Hennepin Station, and Southern Company's Gulf Power Crist Generating Plant, respectively. Although North Dakota lignite has been confirmed as viable feedstock in the laboratory, it has not yet been tested at commercial scale.

This proposal seeks Lignite Research Council (LRC) support to test the commercial application of EPRI's patented mercury control technology (SAP) at commercial scale and over a longer duration on North Dakota lignite at Great River Energy's Coal Creek Station. This technology has the potential to save the North Dakota utilities over 50 percent of the expected annual operating costs of commercially available carbon for mercury control. It has a high probability of near-term commercialization for Great River Energy's Coal Creek Station, as well as other North Dakota utilities. In addition, the SAP concept may generate a new application for North Dakota lignite as a source of activated carbon for use at other power plants.

## 1.2 Expected Results

There are several expected results. First, the project will confirm that North Dakota lignite is a viable feedstock for a commercially scaled SAP in providing activated carbon for mercury control. To date, laboratory tests on a variety of coals would suggest that coal rank and quality do not

significantly affect SAP's ability to produce activated carbon. Second, the project will evaluate Coal Creek Station's baghouse fines that are collected from DryFine processing. These fines are currently a lignite by-product and may prove to be a viable feedstock for SAP, as identified in recent laboratory tests. Third, the project will confirm that SAP generated carbon will preserve ash sales for Coal Creek Station as another cost effective use of lignite by-products. Fourth, the project will assess CaBr optimization as a boiler additive versus as a SAP additive to determine the most cost effective option. Finally, the project will complete an economic analysis and provide a final full-scale SAP design, based on improvements made during the project.

### 1.3 Duration

The current project schedule is expected to take 12-18 months. It will begin by transferring the existing SAP from Illinois to North Dakota, where it will be updated, modified and installed at Coal Creek Station. By fall 2012, the installed SAP will create activated carbon with various lignite feedstocks, as an attempt to assess mercury reduction and/or operational differences, if applicable. As examples, Basin Electric, Minnkota and SaskPower have all offered to send some coal from their respective mines. After these early parametric tests, further modifications to SAP may be implemented, in order to instrument it and to more fully integrate it into plant operations. One feedstock will be selected for a longer duration test (~60-90 days), which is anticipated to occur over the winter-2012 through spring-2013. The long-term tests will provide sufficient data for the project team to provide an engineering economic analysis of potential commercial applications with North Dakota lignite.

### 1.4 Total Project Costs

Total project budget is estimated at $1,045K. The project is seeking $400K from LRC. The remaining funds will come mostly from Great River Energy as combined cash and in-kind contributions, and may also come from EPRI and its members.

### 1.5 Project Participants

There are two primary project participants – EPRI and Great River Energy. EPRI has a strong record of assisting novel control technologies from development phases through commercialization. Great River Energy also has a demonstrated track record of technology development and commercialization including the novel DryFining. In addition, Great River Energy and EPRI have over a decade of experience working together and with other stakeholders on evaluating promising mercury control technology. As needed for this project, other SAP team members including Preferred Utilities Manufacturing, Element One Engineering and Mississippi Lime. The Illinois Prairie Research Institute will be participating to provide design and fabrication support, installation, testing, and laboratory support services under the direct supervision of GRE and EPRI. Most of the "core" SAP team has been collaborating to develop and evaluate SAP since its inception. Finally, several Lignite Energy Council members have agreed to send coal in the support of the project goals.

## 2.0 Project Description

A detailed description of the project, including its objectives; its methodology; its anticipated results; the facilities, resources, and techniques to be used and their availability and capability; the environmental and economic impacts of the project while it is being conducted; its ultimate technological and economic impacts; and why the project is needed.

### 2.1 Project Description, Objectives and Scope of Work

Most coal-fired boilers will need to reduce mercury emissions for compliance with both federal and state regulations. US EPA's recent issuance of the final Mercury and Air Toxics Standards (MATS) has set a firm deadline for compliance. For low rank fuels, like North Dakota lignite, the final MATS mercury limit is <4 lb/Tbtu as a 30-day rolling average. To achieve this emission limit, it is expected that power plants will generally use AC. The delivered cost of commercially available activated carbon is estimated to be in the range of $0.75 to $2/lb (per discussions with suppliers).

Preliminary economic analyses suggest that the amount of activated carbon that would be needed by a 500 MW power plant using ACI to meet its anticipated emission limit could cost $1M to $5M/yr. For the power industry as a whole, this could amount to >$1 billion/year just in AC costs.

EPRI and the Illinois State Geological Survey (ISGS) have developed a technology (U.S. Patents 6,451,094 and 6,558,454) that can significantly reduce the cost of AC for controlling mercury from coal-fired power plants. The technology, called the Sorbent Activation Process (SAP), involves the on-site production of AC at the power plant using site coal and then direct injection of the freshly produced sorbent into the flue gas to capture mercury (Figure 2-1). The process makes use of the concept of rapid gasification (one to two seconds) of fine pulverized feed coal in a long tubular reaction chamber that forms activated carbon. Chemical additives such as bromides and steam are added to the mixture to enhance the reaction. For some applications, the SAP products may be processed through a cyclone collector where the product activated carbon is collected and then injected into the flue gas while the product gas (containing residual CO) is recycled to the boiler. The feedstock coal used can be the same coal burned by the utility. SAP can be used to prepare ACs with various surface areas, pore structures, and surface chemistry from bituminous, sub-bituminous, and lignite coals. The AC is injected upstream of a particulate control device, such as an existing electrostatic precipitator (ESP) or baghouse. In Figure 2-1, the SAP sorbent can be injected either before or after the air pre-heater (APH), ahead of the particulate control device.

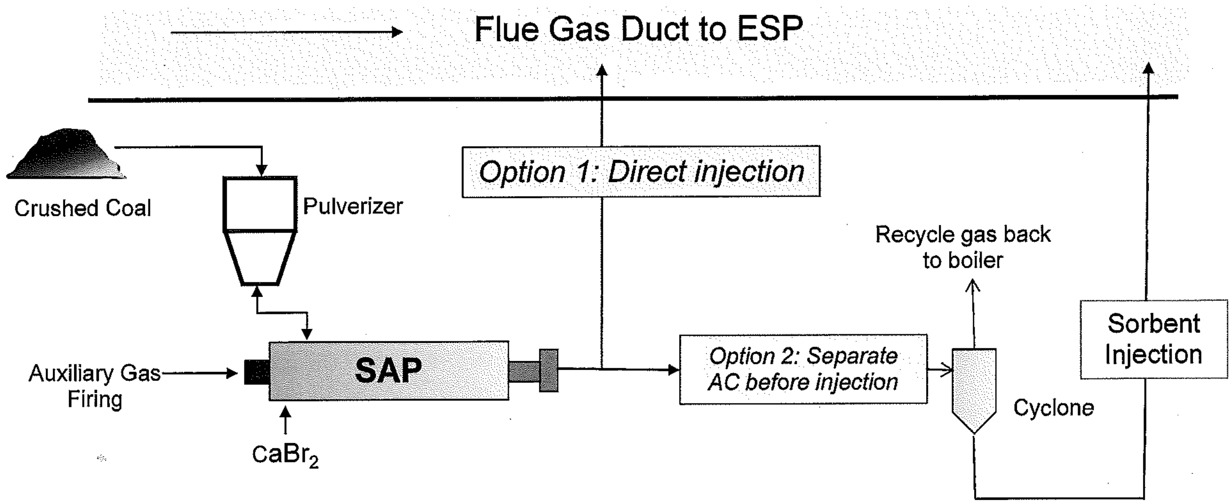


**Figure 2-1 Schematic**

The SAP concept involves three steps:

1. Pulverization of coal into a fine powder and injection into a hot preheated reactor (preheat using auxiliary gas firing or hot flue gas from boiler). The reactor is a long, refractory-lined pipe.
2. Devolatilization, pyrolysis and activation of the fine coal powder into AC. This step occurs in one to three seconds with the volatiles from the coal supplying heat to sustain the reaction.
3. Direct injection of the AC product into flue gas ahead of the particulate collector. An option to direct injection is to separate the carbon from the product gas before direct injection into the flue gas. The separated gas stream returns to the boiler.

By pulverizing feed coal into a fine powder and exposing the powder to very high temperatures (500 to 1400°C [932 to 2,552°F]) for a very short period, SAP reduces the processing time required to produce activated carbon from six to eight hours to just a few seconds and bypasses many of the costly steps associated with conventional activated carbon manufacturing. Since the SAP unit is basically a high temperature reaction and gasification chamber, other chemicals such as limestone, halogen and transition metal salts can be added either to the coal or into the SAP flue gas to produce sorbents and chemicals that can enhance sorbent reactivity with mercury and other air pollutants in the flue gas. Some of these non-carbon additives have proven successful in reducing hazardous air pollutants. For some applications, the SAP products (gas and activated carbon) may be processed through a cyclone collector where the product activated carbon is collected and then injected into the flue gas while the product gas (containing residual CO) is recycled to the boiler.

Given the overall project description, the project team proposes the following scope of work and associated tasks.

1) SAP removal from the Hennepin Station in Illinois
2) Refurbishment and upgrade of SAP components
3) Coal Creek site preparation and coordination

4) SAP shipping and installation
5) Commissioning and startup
6) Parametric testing
7) Long-term operation
8) Data and economic analysis
9) Final report

***Task 1: Removal of SAP equipment from the Hennepin Station***

Under this task the SAP equipment, including the SAP reactor, will be removed from the Hennepin Station in preparation for the relocation of the equipment to GRE's Coal Creek Station.

***Task 2: Refurbishment and upgrade of SAP components***

Various SAP components will be replaced and upgraded. This will include newer design upgrades developed during full-scale testing conducted at other sites.

***Task 3: Coal Creek site coordination and preparation***

This task will assess the best location for setting up the SAP unit, such as installing access ports for injection, conducting flue gas measurements, and locating power and other required utilities.

***Task 4: SAP shipping and installation***

SAP will be shipped to Coal Creek and installed with all necessary ducting and support structure, control and instrumentation, and safety interlocks

***Task 5: Commissioning and startup***

***Task 6: Parametric testing***

Testing will consist of four distinct periods. Testing is assumed to be conducted 12 hours per day. Gas phase measurements for mercury and other flue gas components (NOx, CO, $O_2$) will be conducted with continuous monitors and batch methods. Samples of coal, SAP products, and hopper ash will also be obtained periodically for analysis. A more detailed test plan outlining the test conditions, measurement types and samples will be developed.

<u>Period 1, 3 days: Baseline and commercial activated carbon injection (ACI) testing.</u>

This will help establish baseline mercury removal and additional removal when using a commercial grade activated carbon. Norit's Darco Hg LH will be the most likely candidate. It is expected that the ACI rate will be varied from 0.3 - 2 lb/MMacf over a two-day test period.

<u>Period 2, 5 days: SAP AC testing</u>

Falkirk coal will be pulverized and injected as feedstock into the SAP reactor. A series of parametric tests, varying test conditions such as coal and air feed rate and amount of SAP carbon produced will be conducted. These conditions will be based on the results of the current SAP testing other sites. The SAP effectiveness will be compared to the commercial carbon at similar injection rates.

*Period 3, 3 days: SAP AC testing, DryFine baghouse fines*

DryFine baghouse hopper fines will be used as SAP feedstock and compared to Falkirk site coal SAP AC performance.

*Period 4, 3 to 5 days: SAP AC testing. Other North Dakota lignite coals*

Other North Dakota lignite coals will be tested to assess if there are any variations in SAP AC performance with coal type. It is expected that as many as three different lignites will be evaluated, including coal from Basin Electric's Freedom Mine, Minnkota's Center Mine, as well as coal from SaskPower, consistent with project goals.

***Task 7: Long term operation and associated testing***

Based on the parametric tests conducted above, the optimal feed rate and operating conditions will be selected for extended duration testing to establish that a MATS limit of <4 lb/TBtu can be achieved over a 30-day rolling average period. This task will also include an assessment of boiler bromide addition versus bromide addition to SAP for Coal Creek mercury MATs compliance. It will also include an assessment of ash carbon content to ensure that Coal Creek fly ash is still viable for re-use in the concrete markets.

***Task 8: Data and economic analysis***

The data will be reviewed and used to prepare an engineering economic analysis of the use of North Dakota lignite and Dryfine baghouse hopper catch as SAP feedstocks and cost effectiveness compared to commercial activated carbon injection.

## 2.2 Anticipated Results

This project anticipates several significant results.

1. Confirm that North Dakota lignite is a viable feedstock for commercial production of activated carbon from SAP.
2. Show that North Dakota lignite (Falkirk and other seams) produced SAP carbon is >50 percent lower annual cost than commercially available activated carbons.
3. Show that baghouse fines containing a North Dakota lignite byproduct can be made into a low cost activated carbon source for mercury control.
4. Show that the SAP process (with bromide injection as an option) can help reduce Coal Creek stack emissions to <4lb/TBtu while preserving ash sales.
5. Provide sufficient information to allow GRE and other ND utilities to consider adopting SAP as a cost effective option for compliance with MATS mercury limits.

As a final, and most important goal, the project will further LRC and NDIC goals for promoting lignite and lignite by-product use, as well as in generating more jobs in North Dakota to construct, operate and maintain these complex compliance systems.

## 2.3 Facilities, Resources and Techniques – Availability and Capability

Several critical steps have already been completed in developing the SAP technology. It is now at a point of needing several sites (on different coals with different emission control configurations) for long-term full-scale testing and associated process improvements, EPRI is currently working with a Texas Lignite plant on a similar installation.

Coal Creek Station has a demonstrated ability to integrate and operate technological improvements, as evidenced by DryFining. EPRI continues to provide a critical industry roll in evaluating and guiding technologies from the idea stage through to commercialization.

It is clear that the SAP technology has followed a rigid engineering process of development, ensuring its success. The SAP concept was first assessed on a laboratory scale at the University of Illinois in 2007 (*Sorbent Activation Process for Mercury Control*. EPRI, Palo Alto, CA: 2009. 1016797). The bench scale testing produced activated carbon samples with acceptable mercury adsorption capacity and showed concept feasibility, on a variety of coals. A decision was made to design and build a prototype SAP unit for testing in an actual flue gas using coal available at the power plant site. This prototype unit represented the first of its kind in the world to prove a concept never before tested.

**Prototype - Test Unit Design and Testing (2008 to 2010)**

The prototype SAP reactor is a 35-foot-long tube of refractory approximately three feet in diameter, six inches inside diameter, and about 10 tons in weight. It produced about 30 lb/hr of activated carbon. Early proof-of-concept tests of the prototype were conducted at Ameren's Meredosia station ("On site production of activated carbon for mercury removal from coal flue gas," AQVII, October 26-29, 2009, Arlington, VA). The Southern Company Crist Generation Plant also hosted a test of the prototype. Plant Crist consists of four active units with a total of 930MW of generating capacity. SAP AC was injected into Unit 5, a 70MW boiler that fires Bituminous coal. Unit 5 has a dedicated ESP, a common wet FGD scrubber and stack to all units.

The objective for testing at Crist was to evaluate how SAP performed using site bituminous coal in a bituminous coal flue gas. A secondary objective was to conduct proof-of-concept of using SAP to produce lime from limestone for acid gas removal and co-injection with AC (patent pending). Since this prototype SAP can only produce 30 lb/hr of AC, it can only attain up to 2 lb/MMacf of AC injection concentration when injected into the Crist unit 5. Commercial AC was tested to assess how SAP AC performed relative to commercial AC. The prototype SAP AC injection ranged from 1.29-2 lb/Mmacf with an incremental mercury removal range of 20-35 percent. The commercial Darco Hg LH was injected at 3-7 lb/MMacf and achieved removals of 36-84 percent. Thus, the SAP and commercial AC actually achieved quite similar removals across an ESP in a bituminous coal flue gas at comparable injection rates (~2-3 lb/MMacf). Figure 2-2 shows this data graphically. The mercury removal percentage shown in the table is based on the difference between the inlet and outlet mercury measurements across the ESP.

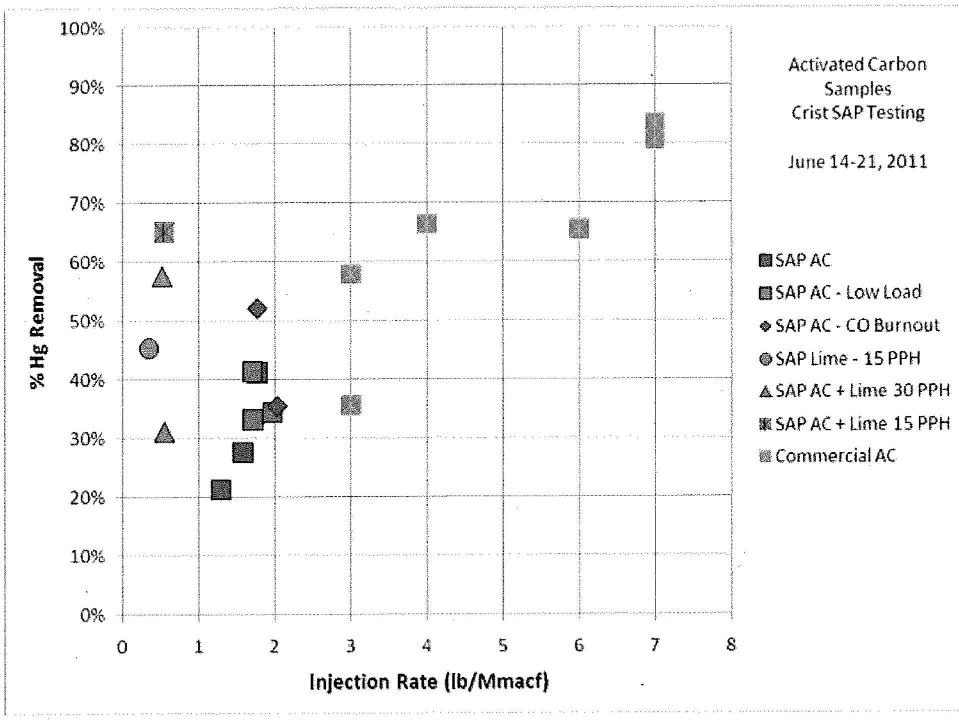


**Figure 2-2 Proto-type Percent Hg Removal vs. Injection Rate**

Figure 2-2 also includes SAP lime sample data. The lime and lime plus SAP AC injection ranged from 0.34-0.65 lb/Mmacf (lime injection was either 15 or 30 lb/hr) and obtained mercury removals of 31-65 percent. Due to the preliminary success of the proto-type SAP, a decision was made to move into a full-scale design.

**Full-Scale - Test Unit Design and Testing (2011-2012)**

The full-scale SAP was constructed, installed and tested at Dynegy Midwest Generation's Hennepin Station Unit 2, which is a 245 MWe, PRB coal fired unit. The SAP unit produced about 90 lbs/hr of activated carbon. This unit has a fabric filter (TOXECON System) following an ESP and a commercial ACI system. The full-scale test objective was to evaluate the performance of SAP generated from PRB coal and injection into a PRB coal flue gas. Full-scale parametric testing at Hennepin lasted for two months. The first month of the test plan included control/software start up, reactor tuning and commissioning of the new unit.

The full-scale SAP reactor is a 21 ft long L-shaped tube of refractory and is approximately 4-1/3 ft in outside diameter. Figure 2-3 shows a cut away view of the unit and each section of the reactor. The horizontal section is the reaction chamber, where the coal and air are injected through the burner and the pyrolysis/sorbent activation occurs. The coal and hot gas travel through 14 ft of the horizontal reactor section and makes a turn upward to the CO burnout and quench sections. The first half of the eight foot vertical section includes water and air injection for CO burnout. After the CO burnout is the quench section where additional water is injected to cool the gas stream for safety. The SAP unit has an independent conveying line, distribution manifold, and injection lances to deliver the AC produced into the flue gas upstream of the fabric filter.

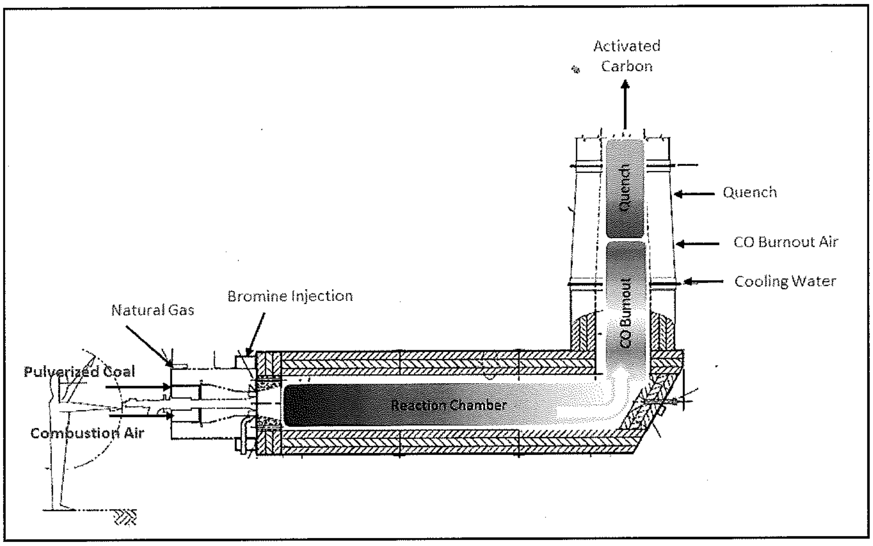


**Figure 2-3 Full-Scale, Side Cut View of SAP Unit**

At this site, the full-scale, SAP AC sample injection rates ranged from 0.85 to 1.89 lb/Mmacf with 63 to 97 percent removal. Calcium Bromide (CaBr) was added to the SAP to further enhance mercury reduction. The average incremental mercury removal was 85 percent over the entire testing period. A graphical representation of mercury removal versus injection rate is shown in Figure 2-4. The graph shows that the majority of the samples was injected at 1-2 lb/Mmacf and was able to remove 78-97 percent mercury. Outliers are suspected to be because of variations in the test conditions. The commercial brominated AC performance used normally at Hennepin is also shown in Figure 2-4 for comparison.

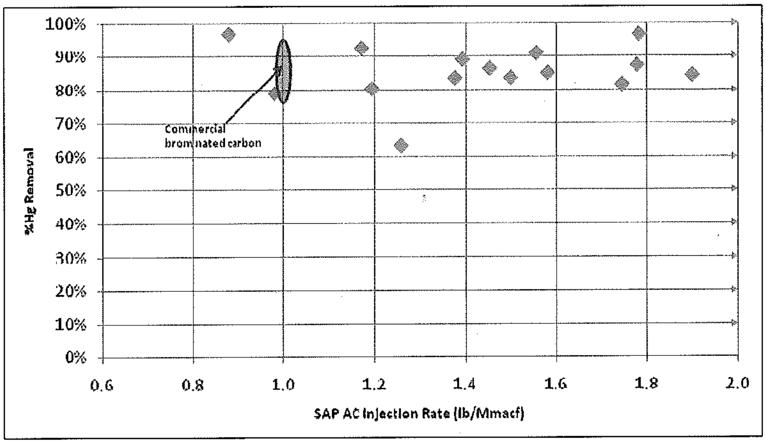


**Figure 2-4 Full-Scale Percent Hg Removal vs. Injection Rate**

The parametric tests conducted at Hennepin to date showed that SAP can produce AC capable of removing up to 97 percent mercury and maintain mercury emissions at 1.2 lb/TBtu, which is the final >8300 btu/lb MACT limit.

The next step in this technology's development is to test lignite, and to test for a longer duration than the prototype and full-scale units, which were relatively short in duration.

## 2.4 Environmental and Economic Impacts

SAP provides significant environmental benefits. It allows a source to control a critical compliance feedstock. Otherwise, a site will be subject to price volatility, and potential supply chain disruptions from out-of-state carbon production facilities, which can not only be costly, but can also lead to non-compliance and/or plant shutdowns.

The simplicity of the SAP concept can also reduce the $CO_2$ footprint for the carbon supply system due to reduced energy consumption. It uses less energy per pound of ACI and does not require shipping when compared with commercially available carbons.

With respect to economic impacts, SAP provides a more cost effective compliance option. This will result in direct savings to electric customers in ND. It will also provide direct jobs in constructing, operating and maintaining the equipment, which would otherwise be sent out of the state.

Activated carbon production facilities could be located near North Dakota lignite mines to supply activated carbon for mercury control in other power plants beyond North Dakota. This ensures the viability of North Dakota lignite as both a fuel and a chemical feedstock in addition to adding more jobs in the region.

## 2.5 Technological and Economic Impacts

With respect to technological advantages, the SAP will provide a site with cost effective, control over a compliance feedstock. As compared to traditional carbon activation, SAP is a superior technology. By pulverizing feed coal into a fine powder and exposing the powder to very high temperatures (700 to 1400°C) for a very short period, SAP reduces the processing time required to produce activated carbon to just a few seconds and bypasses many of the costly steps associated with conventional activated carbon manufacturing (CACM), procurement, transport, storage, handling, and use. As shown in the simplified process flow diagram and photo of a CACM plant in Figure 2-5, numerous steps are involved, including crushing, grinding coal to coarse granules, slow "cooking" in oxidization and devolatilization kilns for hours, and then heating in activation furnaces for more hours. With the complexity of CACM driving AC prices high, the investment cost for a SAP unit, projected to be ~$5-6MM per unit (500 lb/hr activated carbon, enough for 500 MWe unit with ESP), would be recovered in one to three years.

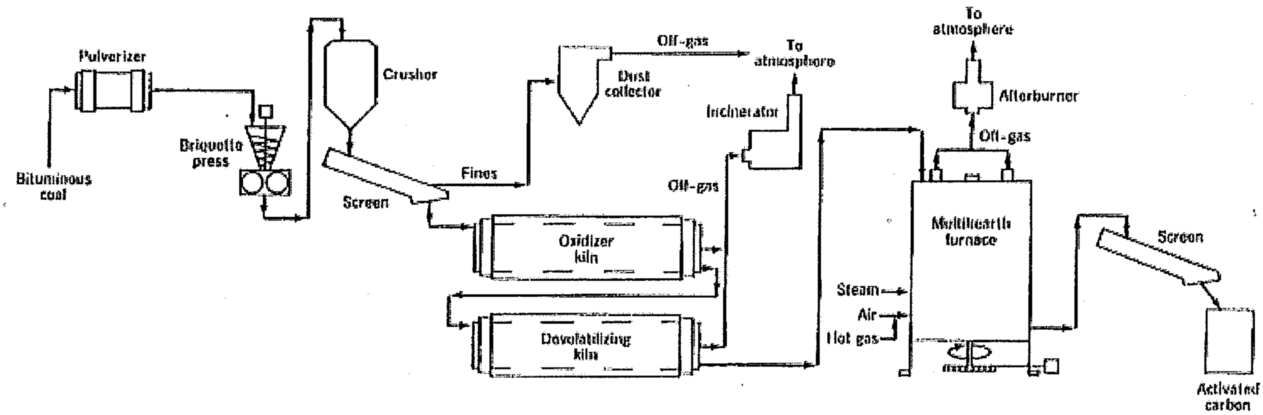


**Figure 2-5 Conventional activated carbon manufacturing**

In addition, SAP will allow a site to use its own coal as a relatively cheap feedstock.

With respect to economic advantages, a host site will need to evaluate the increased capital costs of SAP, and compare it with estimated operational costs as will be expected with commercial activated carbon. It is clear that larger sites, and/or sites with greater mercury reduction requirements, will find SAP to be cost effective.

## 2.6 Why is the project needed?

Despite successful short-term testing at prototype and full-scale to date, there are still many research issues to resolve, which include:

- Confirming North Dakota lignite as full-scale feedstock for generating activated carbon
- Demonstrating long-term operability and durability of this technology
- Making process refinements based on on-site operation and associated testing
- Optimizing the method of pulverizing the feed coal and injecting it into the reaction chamber
- Assessing the optimum coal particle size and reaction time
- Fine tuning the time/temperature history and residence time needed in the reactor for optimal reaction
- Optimizing combustion air needed for volatile matter burnout and porosity formation in the carbon structure
- Demonstrating ability to process widely different coals
- Refining SAP turn-down capability at various boiler loads while maintain constant carbon in ash to preserve ash sales
- Assessing the type and quantity of chemical additives needed to further activate the carbon
- Perfecting the rate of quenching needed at the backend to "freeze the reaction" and inject into flue gas
- Improving options to handle by-products of the SAP process to minimize CO formation and impact on power plant operations
- Minimizing potential for explosive reactions and safety issues

Although the SAP concept development to date has shown significant promise based on short-term testing in a prototype unit, the unit required significant labor to operate manually, and many of the issues presented above could not be resolved in short tests. A more robust unit, including the redesign of specific components to make SAP more adaptable to changing conditions, and longer testing times to look at varying coals, operating conditions, chemical additives, and control effectiveness are critical to establishing the viability of the SAP concept. Initial testing with bromide salt addition to SAP showed that the AC reactivity for mercury could be greatly enhanced.

## 3.0 Standards of success

The standards by which the success of the project is to be measured. This must include an explanation of what parts of the public and private sector will likely make use of the project's results, and when and in what way; of the potential that commercial use will be made of the project's results; how the project will enhance the use of North Dakota lignite and lignite products; how it will preserve existing jobs and create new ones; and how it will otherwise satisfy the priorities established in North Dakota Century Code section 54-17.5-03.

### 3.1 Standards of Success

This project has many potential standards of success. First, it will confirm that North Dakota lignite can be used as a cost-effective feedstock for creating activated carbon at commercial scale, which can be used to comply with mercury limits as finalized in the Mercury and Air Toxic Standards (MATS). If successful, as is expected, this novel technology can provide operational control of a critical compliance feedstock to North Dakota utilities, rather than have them be reliant on vendors and supply chain risks. This will translate into more jobs within North Dakota to construct this technology, to operate/maintain it, and to mine, transport, and continuously feed lignite or lignite products as a compliance feedstock. Second, it will evaluate longer-term operation and make adjustments to the SAP process, including more refined plant integration, automation and instrumentation. The final design will be inclusive of improvements made as part of the project. Third, this project will evaluate a current lignite by-product (baghouse fines) as another useful, cost effective feedstock for controlling mercury. In short, there will be many standards of success, consistent with the commission's research priorities.

### 3.2 What parts of private and public sector will make use of the project results – when and what way?

It is expected that Coal Creek Station will fully integrate this technology as part of its MATS compliance plan on both units. It is expected that improvements, instrumentation, and plant automation improvements will become the basis for a more refined SAP to be installed at Coal Creek.

In addition, the rest of North Dakota utilities will have the benefit of the final design in order to make their own plant compliance, cost effective determinations. It is quite possible that other North Dakota utilities will also pursue SAP as a mercury reduction control strategy.

With respect to the public sector, they will benefit in overall lower cost of electricity when one considers the project cost savings of SAP versus commercially available carbons. Further, the public will generally benefit in job creation to operate and maintain these systems rather than relying on purchasing this product from out-of-state vendors.

### 3.3 Commercial Potential for Project's Results

There is significant commercial potential for the SAP technology. Already, the technology has been scaled from laboratory to pilot scale and then to full scale. This final step will involve longer-term operation, plant integration, instrumentation and automation, as much as feasible. One of the project's success measures will be the final report that will detail the engineering economic feasibility of applying SAP using North Dakota lignite and controlling mercury from North Dakota lignite fired units. The results will also provide a timely option for other ND utilities to comply with MATS by the 2015 deadline. EPRI intends to license the technology quickly following these tests so that interested utilities can adopt them expeditiously. Some of the project team members (Preferred Utilities Manufacturing and Mississippi Lime) have already started considering plans to offer SAP units following the project demonstrations at various sites. The installed cost of a 500 lb/hr activated carbon SAP unit is estimated to be ~$5 to 6 million (including license fees for non-members).

### 3.4 How specifically will the project enhance the use of North Dakota Lignite and Lignite Products?

One of the primary goals of this project is to evaluate lignite as a feedstock for SAP. Lignite has been tested in the laboratory as part of initially developing SAP and was determined to be a viable feedstock for generating AC. North Dakota lignite has never been tested at commercial scale. Upon completing the project, it is expected that North Dakota lignite will prove to be as effective at commercial scale as PRB or bituminous coal in reducing mercury in the exhaust gas. Currently, the market for activated carbon for use in coal-fired power plants as a result of MATS regulations is projected to be >500 million lbs/year. This represents a significant potential high-value market for the use of North Dakota lignite. In addition, this project will evaluate baghouse fines from DryFining operations, which would essentially convert a lignite by-product into a cost-effective compliance feedstock.

### 3.5 How will SAP preserve existing jobs or create new jobs?

As discussed, SAP will provide North Dakota utilities with an on-site option to control a critical and cost-effective compliance feedstock. Rather than purchasing activated carbon and shipping it from another state, it will be generated at the plant with local coal. This will result in an incremental increase in mining, with associated jobs. It will result in an incremental increase in plant personnel to operate and maintain the SAP equipment. It will result in some indirect stimulation of local economies associated with keeping North Dakota revenue circulating within the state economy. It also creates opportunity for construction of new activated carbon processing using North Dakota lignite, especially directly near the coal mines.

### 3.6 How will it otherwise satisfy priorities established in North Dakota Century Code Section 54-17.5-03?

As noted above, it satisfies several of the priorities established in North Dakota Century Code Section 54-17.5-03, by promoting lignite and lignite by-product use, in addition to creating jobs in North Dakota rather than sending them out-of-state to other commercial carbon vendors.

## 4.0 Background and qualifications

A summary of prior work related to the project conducted by the applicant and other participants as well as by other organizations; a summary of the experience and qualifications pertinent to the project of the applicant, principal investigator, and other participants in the project.

The Electric Power Research Institute (EPRI) has played a key role over the last several decades in evaluating novel technologies and in assisting the technologies as they move from laboratory scale through commercialization. With respect to SAP, EPRI has been working with researchers, vendors and utilities for several years as discussed in the Section 3, entitled "Project Description." In addition, EPRI currently holds two patents to the SAP technology; they are U.S. Patents 6,451,094 and 6,558,454.

Great River Energy has recently demonstrated its ability to identify a novel concept (DryFining), and to move it through demonstration phases to commercialization. Over a 10-year period, Great River Energy worked with researchers from Department of Energy (DOE), Lehigh University, and EPRI, as well as numerous vendors and consultants, to make the concept of DryFining an operational reality.

Together, Great River Energy, EPRI and other associated team members are uniquely qualified to fulfill this project's scope.

## 5.0 Management

A description of how the applicant will manage and oversee the project to ensure it is being carried out on schedule and in a manner that best ensures its objectives will be met, and a description of the evaluation points to be used during the course of the project.

### 5.1 Project Management

- EPRI will take the lead to ensure smooth integration of the technology with Great River Energy's Coal Creek Station.
- The core team will design, fabricate, and test a fully-controlled, full-scale SAP unit at Coal Creek Station over an extended period (12-18 months). Under EPRI leadership, this team has designed and tested a prototype SAP unit at full-scale that produced an activated carbon with mercury capture performance similar to that achieved by conventional commercially-produced sorbents (but at a projected price half that of commercial activated carbon). The core team assembled by EPRI consists of University researchers, small-scale burner developers and fabricators, and field testers. Recently, we added a commercial coal burner designer to help develop a more robust reactor design and provide a state-of-the-art burner control scheme.
- The EPRI project managers and advisors (PMs: Ramsay Chang and Cassie Shaban; Advisors: Tony Facchiano and George Offen) are well known experts in the technologies required for this effort – mercury, air toxics, criteria pollutant, combustion R&D and field testing. Members of this team have a track record for developing first-of-a-kind systems and

bringing them from concept to adoption by power plants (e.g. TOXECON and air staging for cyclone boilers). They will continue to be involved in this project as they have been to date.

- Great River Energy has extensive experience evaluating novel mercury reduction technologies in conjunction with EPRI, DOE, and EERC. Most recently, GRE has moved DryFining™ from concept through commercial installation, as a novel multi-pollutant reduction control technology. (PMs: Charlie Bullinger, Diane Stockdill, and Greg Archer.)
- The prototype and full-scale SAP testing conducted by EPRI, electricity generation companies, and the Illinois Clean Coal Institute has demonstrated feasibility of the concept. Therefore, it is ready for process optimization and longer-term evaluation. Total funding to date from these sources amounts to around $1.5M. As one of the last steps in SAP's technological development, EPRI will ship the existing full-scale SAP unit to Great River Energy's Coal Creek Station for further R&D.
- As the technology's value is proven, EPRI technical staff will seek combustion system designers, suppliers and other companies that could be responsible and effective commercializers for this system. EPRI technical staff will then seek management approval to embark on an effort to find and license commercializers in advance of the MATS compliance timeline.

**PM Contact Information**

| | | |
|---|---|---|
| Ramsay Chang | 650-855-2535 | (rchang@epri.com) |
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| Greg Archer | 763-445-5206 | (garcher@grenergy.com) |

**REFERENCES**

1. Chang, R.; Rostam-Abadi, M.; and Sjostrom S. 2002. *Methods for Removal of Vapor Phase Contaminants from a Gas Stream by In-Situ Activation of Carbonaceous Sorbents*. U.S. Patent 6,451,094.
2. Chang, R.; Rostam-Abadi, M.; and Sjostrom, S. 2003. *Methods for Removal of Vapor Phase Contaminants from a Gas Stream by In-Situ Activation of Carbonaceous Sorbents*. U.S. Patent 6,558,454 B1
3. Chang, R.; Ebner, T.; Fisher, K.; Lu,Y.; Morrical, R.; Rostam-Abadi, M.; Shaban, C.; and Slye, R. *On-Site Production of Activated Carbon for Removal of Mercury from Coal Flue Gas*. MEGA Symposium. 2009

## 5.2 Description of evaluation points

There will be several critical evaluation points. (See also Sections 2.1 and 2.2) The first evaluation point will involve the successful de-construction, packaging, shipping and re-construction of the full-scale SAP. It is expected that this will occur over the summer of 2012. The next critical step will involve commissioning, startup and operation of the full scale SAP, which is expected to begin in the fall of 2012 through winter 2013. During initial operation, there will be a few primary objectives. Falkirk lignite and DryFine baghouse fines will be assessed, at a minimum. In addition, other lignites will be tested to assess any potential differences in lignite feedstocks. As examples, Basin Electric, Minnkota and SaskPower have all offered to send some coal from their respective mines in support of the project goals. A commercial activated carbon such as Darco HG LH will be tested for a few days to establish the baseline removal effectiveness to compare with SAP produced activated carbon. Any balance-of-plant impacts observed, including CO emissions, will be assessed and minimized. Adjustments and changes to the SAP design may be implemented to further optimize SAP performance and operation before embarking on long-term testing.

Following these short-term tests, one feedstock will be selected and tested over a longer-term (60-90 days). This phase will involve assessment of long-term operation, SAP performance, and associated plant integration including instrumentation. A final project report will be prepared as a deliverable.

## 6.0 Timetable

A project schedule setting forth the starting and completion dates, dates for completing major project activities, and proposed dates upon which the interim reports required by section 43-03-05-8 will be submitted.

| Timeline | Phase | Subtasks | Notes |
|---|---|---|---|
| Summer 2012 | Mobilization | 1) Deconstruct and transport full scale SAP from Illinois<br>2) Design updates and modifications to SAP for Coal Creek application<br>3) Coal Creek site preparation and installation design<br>4) SAP installation at Coal Creek<br>5) Integrate with plant systems<br>6) Construct coal feed to accommodate both baghouse fines and alternative lignite coals<br>7) Identify alternative lignites, as available, complete SAP commissioning (~2 months) | |
| Fall – Winter 2012 | Short-Term Tests | 1) Conduct short-term (daily) test of various feedstocks<br>2) Evaluate differences between lignite feedstocks<br>3) Identify optimal feedstock for longer-term tests between baghouse fines and Falkirk lignite<br>4) Issue preliminary results of mercury reductions and associated performance of various feedstocks<br>5) Assess options to minimize CO emissions<br>6) Make SAP adjustments to equipment, instrumentation to optimize and accommodate long-term tests | |

| | | | |
|---|---|---|---|
| Spring 2013 | Long-Term Tests (60-90) days | 1) Start long-term tests<br>2) Identify ideal feed rate to achieve 30-day rolling compliances with MATS limit (<4.0 lb/Tbtu)<br>3) Assess CaBr addition to boiler versus to SAP, as a more cost effective use of chemical additives<br>4) Collect periodic ash and scrubber liquid and solids samples to measure balance of plant impacts, and confirm ash sale viability | |
| Summer 2013 | Final Assessment of SAP commercial potential for ND lignite applications | 1) Review and summarize all data to date<br>2) Conduct final engineering economic analysis of SAP and compare with commercial carbon and/or CaBr reduction options<br>3) Issue final project report based in feedback from presentations and economic analysis | |

## SAP Project Timeline

| | 2012 | | | | | | | | 2013 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Task** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **July** |
| Project kickoff | X | | | | | | | | | | | | | | |
| SAP removal from the Hennepin Station | | | XX | X | | | | | | | | | | | |
| Refurbishment & upgrade of SAP components | | | XX | XX | | | | | | | | | | | |
| Coal Creek site preparation and coordination | | | X | XX | | | | | | | | | | | |
| SAP shipping and Installation | | | | | XX | XX | | | | | | | | | |
| Commissioning and startup | | | | | | | XX | | | | | | | | |
| Parametric testing | | | | | | | X | XX | | | | | | | |
| Long-term operation | | | | | | | | | | XX | XX | XX | | | |
| Data and economic analysis | | | | | | | | | | | | X | XX | X | |
| Final report | | | | | | | | | | | | | | | XX |

## 7.0 Budget

An itemized list of the project's capital costs; direct operating costs, including salaries; indirect costs; and an explanation of which of these costs will be supported by the grant and in what amount. Identification of all other committed and prospective funding sources and the amount of funding from each source, differentiating between cash and in-kind services. An explanation why the funding requested is necessary to achieve the project's objectives and, if less funding is available than that requested, whether the project's objectives will be unattainable or delayed.

| Timeline | Phase | Budget | Notes |
|---|---|---|---|
| Summer 2012 | SAP removal from Hennepin, SAP modifications, transportation, and installation at Coal Creek | $505K | GRE/EPRI provide in-kind mechanical and electrical (cranes, trucks, labor)<br>Cash for SAP upgrades/shipping from GRE/EPRI |
| Fall-Winter 2012 | Short-Term Tests | $210K | GRE/EPRI contracts SAP operation and testing. GRE/EPRI/LRC cash will be used to fund tests. |
| Spring 2013 | Long-Term Tests (60-90) days | $210K | GRE/EPRI contracts SAP operation and testing. LRC cash will fund tests. |
| Fall 2013 | Data/Economic Analysis and Final Assessment of SAP's Commercial Potential for ND Lignite | $120K | GRE/EPRI/LRC cash will fund analysis and final report. |
| | | Total = $1,045K | |

The total project budget is estimated at $1,045K. Of this amount, GRE and EPRI plan to contribute $350K cash and $295K in-kind, as noted below. The project participants are requesting that LRC provide remaining $400K cash to fund testing and the final report.

In the summer of 2012, the project expects to spend $250K cash with the remainder coming from in-kind contributions of labor and equipment from the project participants. It will involve disassembly and upgrades to the existing SAP and will require shipping from Illinois to North Dakota as estimated below.

In addition, the summer 2012 costs involve SAP installation and commissioning at Coal Creek. (These installation costs are based on comparable costs as incurred at the Hennepin Station.)

Coal Creek expects to use plant labor for some of the mechanical and electrical installations, as "in-kind" contributions.

During the short-term testing phase in the fall of 2012, EPRI contractors are expected to cost $210K for a combination of on-site operation of SAP and emission testing. EPRI contractors will make efforts to instrument, automate, and train CCS plant staff to assume as much operational control over SAP, in order to keep the project costs as low as possible. Project funds will not be used to compensate CCS staff. As noted in the project description, the on-site tests will focus on various lignite feedstocks, and chemical additives, with their associated mercury reductions. Testing fees will cover on-site continuous mercury monitoring, as well as periodic scrubber solids, liquids and ash samples with associated lab fees. Coal Creek's lab will provide "in-kind" coal sampling and analysis as needed. Headwaters will be engaged for ash assessments, as necessary.

The longer-term tests are estimated to be the same as the parametric test, at $210K. It assumes that CCS staff will take over some operational control of the SAP, which will reduce contractor on-site time and overall project costs. In addition, it assumes that the test contractor will be able to remotely check on monitors during the extended run.

EPRI and GRE will work with the project contractors to provide engineering and potentially parts as additional "in-kind" contributions as SAP process refinements are identified and implemented. In order to keep the overall budget lower, Great River Energy will contract directly for construction and commissioning services rather than through EPRI, which reduces EPRI overhead. GRE will receive funds from LRC and pay contractors, including EPRI and their subcontractors, accordingly.

The matching funds are needed to provide for an adequate evaluation of long-term SAP operation on North Dakota lignite. Without full funding, the project may still continue, but with a reduced scope that would limit continuous operation and the associated process refinements. Eventually, SAP needs to be demonstrated at 60-90 days to fully understand its operating characteristics in order to successfully refine, instrument and automate it. Partial funding may still allow some of these refinements to occur. As a potential option, approximately $300K will be spent in 2013 on the longer term testing, data/economic analysis and final report generation. Therefore, it is possible for the LRC and Great River Energy to allocate funds over a two-year period, if that makes sense from a financial perspective.

## SAP Budget of Cash and In-kind Contributions by Task

| | Labor ($k) | | | Capital (equipment & supplies) ($k) | | | Total ($k) | |
|---|---|---|---|---|---|---|---|---|
| **Task** | In-kind | Cash from GRE/EPRI | LRC funding | In-kind* | Cash from GRE/EPRI | LRC funding | In-kind | Cash |
| Project kickoff | 50 | | | | | | 50 | |
| SAP removal from the Hennepin Station | 10 | 75 | | 25 | | | 35 | 75 |
| Refurbishment & upgrade of SAP components | 10 | | | | 75 | | 10 | 75 |
| Coal Creek site preparation and coordination | 10 | | | | | | 10 | |
| SAP shipping and installation | 90 | 50 | | 50 | 50 | | 140 | 100 |
| Commissioning and startup | 10 | | | | | | 10 | |
| Parametric testing | 10 | 50 | 150 | | | | 10 | 200 |
| Long-term operation and testing | 10 | | 200 | | | | 10 | 200 |
| Data and economic analysis | 10 | 50 | | | | | 10 | 50 |
| Final report | 10 | | 50 | | | | 10 | 50 |
| | 220 | 225 | 400 | 75 | 125 | 0 | 295 | 750 |

* Capital cost of $1MM to build initial SAP is not included

| | |
|---|---|
| LRC Funding | 400 |
| GRE/EPRI Funding | 350 |
| GRE/EPRI In-Kind | 295 |
| Total Project | 1045 |

## 8.0 Tax liability

An affidavit stating that the applicant does not have an outstanding tax liability owed to the State of North Dakota or any of its political subdivisions.

Neither Great River Energy nor EPRI has an outstanding tax liability owed to the state of North Dakota or any of its political subdivisions.

## 9.0 Confidential information

Any information in the application that is entitled to confidentiality and which the applicant wants to be kept confidential should, if possible, be placed in an appendix to allow for administrative ease in protecting the information from public disclosure while allowing public access to the rest of the application. Such information must be clearly labeled as confidential and the applicant must explain why the information is entitled to confidentiality as described in North Dakota Century Code section 54-17.5-06.

GRE and EPRI do not view this information as confidential.