April 1, 2014

Ms. Karlene Fine
North Dakota Industrial Commission
State Capitol
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Subject: Grant Application for the NDIC/Lignite Energy Council Funding

Dear Ms. Fine,

Envergex LLC and the University of North Dakota are pleased to submit a grant application to the North Dakota Industrial Commission and Lignite Energy Council for consideration for funding.

The proposed project will further advance the technology for capturing CO_2 from coal-fired boilers. Under a Phase I U.S. Department of Energy SBIR/STTR project, our Enhanced Capture of CO_2 by Hybrid Sorption (E-CACHYS™) technology achieved a quantum increase in the carbon dioxide capacity over current sorbents (7 to ~15 g CO_2/100 g sorbent). The proposed Phase II project will scale up methods to produce the advanced sorbent and test its CO_2 capture performance at an existing slipstream test facility at the University of North Dakota.

Proposed funding for this 2-year Phase II project is approximately $1,000,000 from the U.S. Department of Energy and with additional funds of $100,000 from ALLETE (Minnesota Power and BNI Coal - $25,000), SaskPower ($25,000), and NDIC/LEC ($50,000). Duration of the project is July 2014 to June 2016.

A check for $ 100.00 is enclosed for proposal filing fees. Please contact me if you have any questions or need additional information for the enclosed grant application.

Sincerely,

Srivats Srinivasachar, Sc.D.
President, Envergex LLC

cc. Steven A. Benson, UND

Enclosure: Grant Proposal

Enhanced High Capacity Sorbent and Process for CO_2 Capture Using Hybrid Sorption (E-CACHYS™)

Submitted to:

Ms. Karlene Fine
North Dakota Industrial Commission
State Capitol
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Proposal Amount: $50,000

Submitted by:

Srivats Srinivasachar, Sc.D.
President
Envergex LLC
10 Podunk Road
Sturbridge, MA 01566-1064

Srivats Srininvasachar, President
Envergex LLC

April 1, 2014

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ABSTRACT

Under a Phase I US Department of Energy Small Business Innovative Research/STTR project, Envergex and the University of North Dakota developed and demonstrated the Enhanced Capture of CO_2 by Hybrid Sorption (E-CACHYS™) technology and sorbents that achieved a quantum increase in the carbon dioxide capacity over the current CACHYS™ sorbents from 7 to ~15 g CO_2/100g sorbent. The technology captures CO_2 from flue gases at typical scrubber exit temperatures, while minimizing large solids handling and circulation requirements, and has a low total energy for regeneration. The E-CACHYS™ sorbent capacity increase was achieved by using tailored sorbent support materials with physical characteristics that have the capacity to hold the active component and with advanced methods to distribute increased proportions of the active component in the sorbent. The proposed Phase II project will scale-up methods for producing the E-CACHYS™ sorbents to maximize the CO_2 loading capacity. In addition, an enhanced process configuration that (i) reduces sorbent attrition, (ii) accommodates operation with a finer particle size distribution, and (iii) incorporates a method to increase sorbent life, will also be demonstrated.

Our team–Envergex LLC, University of North Dakota, and Solex Thermal Sciences along with industrial support from ALLETE (Minnesota Power and BNI Coal), SaskPower and North Dakota Industrial Commission – is uniquely qualified to develop the E-CACHYS technology. Proposed funding for the Phase II effort is $1,000,000 from the US DOE and with cost share of $100,000 from ALLETE (Minnesota Power and BNI Coal), SaskPower, and NDIC. This effort will enable migration of the concept to the next scale (pilot) and eventually to full-scale demonstration and commercialization. The duration of the project is two years beginning July 1, 2014 and ending June 30, 2016.

PROJECT SUMMARY

The overall objective of the proposed Phase II research is to continue development of the E-CACHYS™ hybrid sorbent technology that significantly reduces the cost of carbon dioxide capture by providing a quantum increase in the carbon dioxide holding capacity of the sorbent while also providing increased reaction rates, low energy requirements and a simple process configuration, in addition to a low cost sorbent.

Phase I developed and demonstrated the technology at the laboratory-scale, with specific emphasis placed on achieving a quantum increase in the carbon dioxide capacity of the sorbent (~15 wt% of sorbent). Increases in sorbent capacity were achieved by using tailored sorbent support materials with physical characteristics that have the capacity to hold the active component and with advanced methods to distribute increased proportions of the active component in the sorbent.

Phase II research will develop improved sorbent manufacturing methods that will increase uniformity and reactivity of the active component in the support structure. In addition, a new operational philosophy is proposed that will greatly reduce the impact of sorbent attrition by substantially increasing the useful life of the sorbent, thus reducing sorbent replacement costs. This new philosophy will include a simpler equipment configuration that will be installed and demonstrated at the current slipstream testing facility at UND using actual coal-combustion derived flue gas.

Our team – Envergex LLC, University of North Dakota, and Solex Thermal Sciences along with industrial support from ALLETE (Minnesota Power and BNI Coal), SaskPower and North Dakota Industrial Commission/Lignite Energy Council – is uniquely qualified to develop the E-

CACHYS™ technology. The project will enable migration of the concept to the next scale (pilot) and eventually to full-scale demonstration and commercialization. In the project, the following tasks are proposed.

Task 1 - Project management, planning and reporting

Task 2 - Lab-scale development of enhanced sorbent manufacturing methodology

Task 3 - Lab-scale development of sorbent reuse methodology

Task 4 - Evaluation of sorbent performance and attrition characteristics

Task 5 - Modification of existing slipstream testing facility

Task 6 - Production of sorbent for slipstream facility testing

Task 7 – Slipstream testing of enhanced sorbent and process

Task 8 - Economic analysis and development of commercial methodologies

The project will develop key information for the E-CACHYS™ process - sorbent performance, energy for sorbent regeneration, physical properties of the sorbent, the integration of process components, sizing of equipment, and overall capital and operational cost of the integrated E-CACHYS™ system. An efficient, reliable, and cost-effective process for CO_2 capture with solid sorbents will be developed.

PROJECT DESCRIPTION

Goals and Objectives

This project targets the development of novel sorbents with two principal objectives: (1) maximizing sorbent capacity and improving the rate of CO_2 capture, thus reducing capital and operating costs for CO_2 capture and (2) minimizing the energy for CO_2 capture and separation using ultra-high capacity sorbents in combination with a low-energy requirement hybrid sorption process. Development of a cost-effective CO_2 capture and separation technology will facilitate the continued use of North Dakota lignite for power generation while minimizing greenhouse gas emissions.

Work Plan

Task 1 – Project management, planning, and reporting: This task will include coordination and planning of the project with DOE-NETL and other project participants/sponsors. This task will accomplish preparation and submission of technical reports and meeting reporting requirements.

Task 2 – Laboratory-scale development of the enhanced sorbent manufacturing methodology: Several strategies have been identified to improve the sorbent manufacturing process, specifically methods to improve impregnation. This task will include testing of these strategies, followed by evaluation of the sorbent performance using the existing laboratory-scale fixed/bubbling bed capture system at UND.

Task 3 – Laboratory-scale development of sorbent reuse methodology: Methods for reusing under-sized sorbent fines (e.g. briquetting) will be evaluated to greatly reduce fresh sorbent replacement costs. UND will fabricate, install and operate the test equipment. Envergex will lead the development of the test protocols.

Task 4 – Evaluation of sorbent performance and attrition characteristics: This task will comprise three subtasks: 4.1) Determination of reformulated sorbent attrition characteristics; 4.2) Determination of reformulated sorbent flowability; and 4.3) Evaluation of CO_2 capture performance with reformulated sorbents.

Task 5 – Modification of existing bench-scale slipstream facility: This task will include installation of improvements and modifications to the existing CACHYS™ slipstream facility.

Task 6 – Production of sorbent for bench-scale testing: This task will be completed in two subtasks:

6.1 Modification of the sorbent production facility: Based on the results of Task 2, additional equipment will be purchased and integrated with the existing sub-pilot scale sorbent production facility.

6.2 Sorbent manufacturing: Following the methodologies identified during Task 2, a sufficient quantity of sorbent (~2000 lbs), will be manufactured for testing in the slipstream facility.

Task 7 – Slipstream testing: This task will include testing of the advanced sorbent with the sub-pilot scale facility using a slipstream of actual coal-combustion flue gas from the UND steam plant. Testing will include three phases. The first phase will include shakedown testing of the new components installed during Task 4 followed by making any necessary modifications or additions identified. The second phase will consist of a series of short parametric tests aimed at optimizing specific parameters or aspects of the system. Following completion of the parametric testing, the third phase consists of a series of continuous tests that will be accomplished with optimized conditions. Parametric testing will consist of short-duration tests aimed at optimizing specific parameters of the E-CACHYS™ process. These tests are expected to be approximately 8-12 hours. In between each run, sorbent samples and data will be analyzed, and the results used to direct goals/test conditions for the subsequent test series. Following parametric testing, continuous testing of the fully-integrated, bench-scale process will be conducted with longer-term tests on the order of 2-3 days (24 hour operation, ~60 hrs), followed by sufficient time to analyze data and determine changes for the next test. Two (2) such continuous tests will be conducted.

UND will perform the testing. Envergex will develop the test matrices and protocols, participate in testing, and lead the data reduction effort.

Task 8 – Economic analysis and development of commercial methodologies: This task will include an evaluation of the economics of the proposed technology, including a conceptual design of a commercial facility and manufacturing methodologies. The overall impact of retrofitting an existing coal-fired plant with the system will be determined. Also included in this task will be the final Phase II technical report.

DELIVERABLES

The primary deliverable of the entire project will be quarterly reports and a final report that will include a detailed explanation and supporting experimental and testing results that will be conducted to support the proposed E-CACHYS™ concept. The final report will identify the specific strategies applied in the capture of CO_2 from coal-fired boilers, an updated technical and economic feasibility for the retrofitting of a carbon capture system to a 500MW plant, and an environmental health and safety assessment. Further, the quarterly reports as well as the final report will be provided for comments and revision.

STANDARDS OF SUCCESS

The overall success of the project will be based on the ability to make progress in decreasing the cost of CO_2 capture. The DOE goals are to develop advanced CO_2 capture and separation technologies that can achieve at least 90% CO_2 removal at no more than a $40/ton cost for CO_2 separation and less than 35% increase in cost of electricity (COE) produced at the plant. This project's standard of success is based on the E-CACHYS™ technology to make significant progress towards achieving DOE's goal.

BACKGROUND

The Problem – In the US, coal-fired power plants represent about 42% of the electricity generated but contribute about 75% of the CO_2 emissions. Coal-fired plants represent a very large concentrated stationary emission source and are the best target to address the challenge of CO_2 emission mitigation. A primary approach to reduce emissions from coal combustion is to capture and store the CO_2 (CCS). After capture, the CO_2 is compressed to about 2200 psi for delivery to sequestration reservoirs or for enhanced oil recovery. This proposal focuses on the CCS option.

Many commercial post-combustion CO_2 capture plants use chemical absorption with amine-based solvents (e.g. monoethanolamine – MEA). Concerns about degradation and corrosion have kept the solvent strength relatively low (typically 20-30% amines by weight in water), resulting in large equipment sizes and solvent regeneration costs (Farthing, 2012). Existing amine-based absorption systems have a number of disadvantages including high parasitic steam loss during solvent regeneration, sensitivity to sulfur oxides and oxygen, solvent loss due to vaporization, and high capital and operating costs.

An alternate capture strategy is the use of solid sorbents. Solid sorbents may have advantages because of potentially lower energy requirements, as the heat capacity of the solid carrier is several times lower than the water in the MEA-based solvent. The Dry Carbonate Process being developed by RTI (Nelson, 2009) makes use of the well-known reaction chemistry of sodium carbonate (Na_2CO_3) and sodium bicarbonate ($NaHCO_3$). The reversible carbonation reaction inherent to this process is as follows:

$Na_2CO_3(s) + CO_2(g) + H_2O(g) \rightarrow 2NaHCO_3(s)$ $\Delta H_r = -135$ kJ/mole of CO_2 (Reaction 1)

There are, however, significant challenges: The CO_2 sorption process is strongly exothermic and requires significant cooling. The reaction will not proceed if temperatures are not controlled. The regeneration (reverse) reaction imposes an equivalent large energy penalty to heat the sorbent and release the CO_2.

Recently, Benson and Srinivasachar (2012) have developed a hybrid sorption process (CACHYS™) with significantly reduced regeneration energy. The CACHYS™ technology has a relatively low heat of sorption (40-80 kJ/mol CO_2) compared to the Dry Carbonate Process. However, the CACHYS™ process could benefit significantly by having a sorbent with higher CO_2 loading capacity.

Another solid sorbent technology that has shown some promise is a high surface area carbon sorbent, which captures CO_2 via physical sorption (Krishnan, 2012). This process has a low heat of sorption (~ 30 kJ/mole of CO_2). However, to achieve a reasonable CO_2 capacity (5-7 g/100 g sorbent), the adsorption step requires operation at very low temperatures (~20°C). This would require significant cooling of the flue gas leaving the coal-fired boiler system. A sorbent that would be able to have higher CO_2 capacity at higher temperatures with similar sorption energy would be desirable.

Begag et al. (2013) have developed a novel solid sorbent for CO_2 capture using amine functionalized aerogel (AFA) for a temperature swing process (adsorption-40°C/desorption-130°C), with good working capacity (6.3 g of CO_2/100 g of fresh sorbent) and resistance to steam. However, the working capacity was lowered (by 50%) when the material was formulated into pellets and milled for larger-scale testing.

The target for our proposed project is to develop sorbents that maximize the CO_2 loading capacity of the solid sorbent at typical scrubber exit temperatures, minimizing large solids handling and circulation requirements and sensible heat losses, and reduce the total energy of regeneration. In addition, an enhanced process configuration that (i) reduces sorbent attrition, (ii) accommodates operation with a finer particle size distribution, and (iii) adds a method to increase sorbent life, will be demonstrated.

The Solution and Proposed Concept – Our approach uses low cost starting materials and relatively simple and scalable manufacturing methods that will result in low cost sorbents. The active component in the sorbent is non-volatile, thus having no negative environmental impacts. The reaction chemistry is inherently fast but with low reaction energies, and enhanced by our process conditions. The capacity is maximized by increasing the active component proportion and ensuring uniform distribution in the support structure.

Sorbent Formulation: The proposed sorbents are formulated to meet the requirements in Figure 1 and consist of an alkali carbonate-based active component supported by advanced substrate materials. The reactive elements in the proposed sorbent are the same as the ongoing CACHYS™ project; they therefore exhibit the desirable low energy of reaction characteristics. However, the proposed formulation is made with a geometry and sorbent structure that explores the potential of maximizing the content, capacity, and activity of the reactive components.

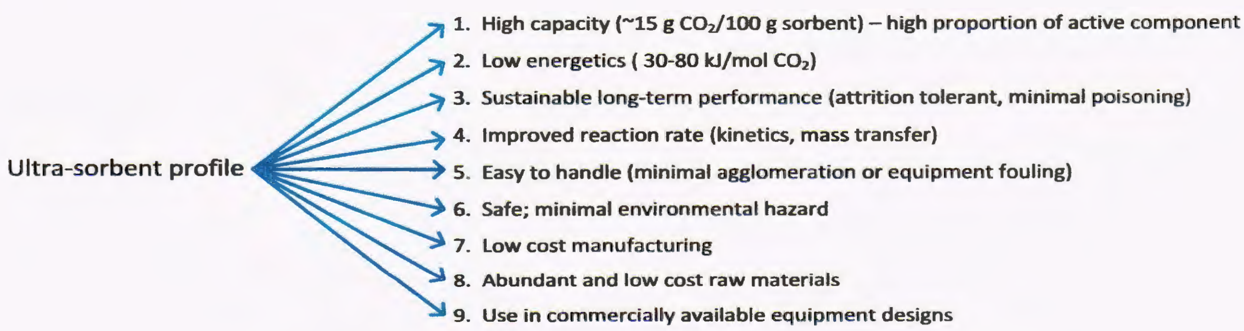

Figure 1. Characteristics of the proposed sorbents for CO_2 capture

A detailed technical basis of the proposed work, supporting data from previous research work, and detailed work plan are provided in the Confidential Appendix D.

QUALIFICATIONS

Project Team

Envergex LLC

Dr. Srivats Srinivasachar is President of Envergex LLC and also an adjunct faculty member of Chemical Engineering at the University of North Dakota (UND). Dr. Srinivasachar has an ongoing Department of Energy STTR project with UND (basis of proposed project) related to the capture of CO_2 from flue gases using solid sorbents. Dr. Srinivasachar holds 10 patents and has over 50 publications, several of these related to pollution control technology. He is a world class expert on the subject of mercury control. He is the inventor and developer of enhanced mercury control sorbents (ESORB®, patents pending) which have been tested in several full-scale boilers and are being commercialized. He scaled the product through pilot-scale evaluation and commercial-scale testing, including commercial-scale production of sorbents, and completed the successful demonstration of this technology at three full-scale plants.

UND Institute for Energy Studies

Dr. Steve Benson is the Director of the Institute for Energy Studies and a professor of Chemical Engineering at the University of North Dakota (UND) and is a sub-contractor in this effort. Dr. Benson has over 25 years of experience of coal related research centering on coal, biomass, and petroleum energy conversion systems; air pollution control; and CO_2 separation and capture. Currently, Dr. Benson has active projects in trace metal transformation, ash formation, NOx control, mercury emissions control, and CO_2 separation and capture sequestrations. Prof. Benson has a well equipped laboratory and works with a very capable team of faculty/staff research engineers, equipment fabricators, and graduates students working on coal combustion and gasification related projects and has the capability of pilot-scale coal combustion and scrubber testing, sampling and analysis of combustion gases and ash, and mercury and trace element analysis.

Dr. Michael Mann, Associate Dean for Research, School of Engineering and Mines, has extensive experience in fluidized bed combustion and gasification systems. Specifically he was involved in research projects; design, installation, and operation of a 1 MW_{th} CFBC and a 250 lb/hr gasifier. In addition, he was a manager for project for the development of small power systems for Alaskan villages; and the development of a small-modular fluid-bed combustion system (0.5 to 5 MW).

Facilities

TGA/DSC (Existing - UND) – UND has two TGA/DSC systems. The units allow thermo-gravimetric analysis and differential scanning calorimetry on a solid sample as it undergoes reaction or phase change. The systems will be used in the proposed project to determine sorbent heats of reaction as well as measure the utilization of various sorbent samples from bench and lab-scale testing.

Laboratory-Scale Fixed/Fluid Bed Reactor System (Existing - UND) –The reactor is typically operated in a bubbling fluidization mode to gather data on adsorption and desorption performance, working capacity and multi-cyclic operation. The system has been used extensively during the Phase I work and will be used to evaluation the performance of sorbents produced during Phase II.

Slipstream Bench-Scale CACHYS™ System (Existing - UND) –The bench-scale system captures CO_2 from 30-40 acfm of coal-derived combustion flue gas from UND's steam plant.

The system consists of integrated adsorption and regeneration systems with sorbent throughputs up to 100 kg/hr. This system will be modified during the proposed project to accommodate the improved sorbent and process configuration.

Sub-pilot Sorbent Manufacturing System (Existing - UND) – The existing system will be modified during Phase II to better accommodate the proposed improvements to the manufacturing process. The main components of the existing system are a rotary drum dryer with a throughput of 10-25 lb/hr and a batch impregnation/mixing vessel with a capacity of ~30 lb.

Lab-Scale Attrition Test System (UND) – This system will be fabricated and installed during Phase II. The system will be utilized to determine sorbent particle size distribution as a function of the number of cycles. The system approximates the high velocity and turbulent conditions that are encountered in the adsorber system and will help determine the expected sorbent lifetime.

Lab-Scale Sorbent Briquetting System (UND) – This system will be fabricated and installed during Phase II. This system will consist of an externally heated hydraulic piston-type compaction system capable of exerting up to seven tons of force and will be used to evaluate reformulation methods.

Lab-Scale Substrate Manufacturing System (Existing - UND) – This system consists of a tube furnace and associated components that is used to produce substrates of the ultra-high capacity E-CACHYS™ sorbents. The system was used extensively during Phase I, and will be available for use during Phase II.

Scanning Electron Microscope (Existing – UND) – This is a field emission SEM that has the capability to image the microstructural features of very small pores and particles. The system also has x-ray microanalysis capability and will be used during the proposed Phase II work to examine substrate and sorbent surface features.

Fabrication Facilities (UND) – UND has a fully equipped fabrication facility and includes a complete list of abilities, including welding, machining, electrical, structural and installation services. Experienced and skilled personnel will be utilized to construct and install the proposed equipment.

VALUE TO NORTH DAKOTA

North Dakota produces over 30 million tons of lignite annually. North Dakota's economy depends on lignite production and use. Lignite combustion produces more CO_2 per Btu of energy as compared to other coals, thus a low-cost effective means of separating CO_2 will be critical to ensure lignite's future use if regulations limit CO_2 emissions in the future.

MANAGEMENT

The team assembled to perform the proposed work includes the Envergex LLC, Institute for Energy Studies (IES) of the University of North Dakota, ALLETE (Minnesota Power and BNI), SaskPower, and the Lignite Energy Council. The team brings together the expertise required to effectively perform the proposed work to determine the technical and economic feasibility of the technology that will lead to a commercial system to capture CO_2. The project will led by Dr. Srinivasachar the principal investigators of the project. Dr. Benson will work closely with Dr. Srinivasachar to coordinate the scientific and engineering aspects of the project. Dr. Benson and Dr. Srinivasachar have a long history of working together on projects. Dr. Srinivasachar will coordinate meetings and conference calls with the NETL and other project co-sponsors as well as communications with project participants.

Project meetings and conference calls will be held on a quarterly basis to review project timeline, upcoming milestones/deliverables, costs and challenges associated with the completion of the projects. Microsoft Project management tools will be utilized. Project review meetings with sponsors will also be held on a quarterly basis to ensure communication and discussion of accomplishments, plans, and management of project risks. We will meet with industry co-sponsors to update them on technical progress and seek input on commercial scale-up and applicability.

PROJECT TIMETABLE

The project will be conducted in two (2) 12-month budget periods (BP1: Tasks 1-5, BP2: Tasks 1, 6-8). Task 1 – project management and planning – will extend throughout the duration of the project. Task 5 will extend throughout the duration of budget period 1 and will be conducted co-currently with Tasks 2-4. All other project tasks will be completed sequentially. Figure 2 displays the Gantt chart for the project. Milestones are identified below.

ID	Task Name	Start	Finish
1	Task 1	Tue 7/1/14	Thu 6/30/16
2	Task 2	Tue 7/1/14	Fri 10/31/14
3	Task 3	Sat 11/1/14	Sat 2/28/15
4	Task 4	Sun 3/1/15	Tue 6/30/15
5	Task 5	Tue 7/1/14	Tue 6/30/15
6	Task 6	Wed 7/1/15	Mon 8/31/15
7	Task 7	Tue 9/1/15	Sat 4/30/16
8	Task 8	Sun 5/1/16	Thu 6/30/16

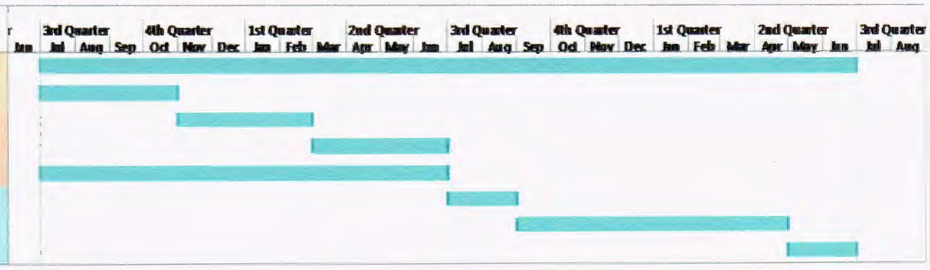

Figure 2. Project Gantt chart – timeline by task and budget period (identified by shading)

Milestones:

BP1

1 – Selection of optimum sorbent manufacturing methodology

2 – Completion of the bench-scale design

3 – Identification of sorbent attrition characteristics/approximation of steady-state particle size

4 – Determination of sorbent flowability and minimum particle size

5 – Selection of optimum sorbent reformulation methodology

6– Completion of installation of bench-scale design modifications

BP2

7 – Complete manufacturing of sorbent for slipstream facility testing

8 – Complete shakedown testing and necessary modifications to slipstream unit

9 – Complete parametric testing at slipstream facility

10 – Complete continuous testing at slipstream facility

11 – Complete final process assessment and process economics evaluation

BUDGET

The budget and budget notes for the overall project is included in Appendix B. Letter of commitment from University of North Dakota and subcontractor budget is attached in Appendix C.

MATCHING FUNDS

Matching funds are provided by ALLETE, SaskPower, University of North Dakota, and U.S. Department of Energy. Letters of commitment are attached in Appendix C.

TAX LIABILITY

No outstanding tax liabilities to the state of North Dakota.

CONFIDENTIAL INFORMATION

Confidential information is contained only in Appendix D.

REFERENCES

1. Conference Proceedings (2012) – "*Annual Department of Energy – NETL CO_2 Capture Technology for Existing Plants R&D Meeting*," Pittsburgh, PA, July 2012 http://netl.doe.gov/publications/proceedings/12/co2capture/index.html

- "Hydrophobic Aerogel Sorbents for CO_2 Capture," Begag, R.
- "Evaluation of CO_2 Capture from Existing Coal-Fired Plants by Hybrid Sorption Using Solid Sorbents" Benson, S.A. and Srinivasachar, S.
- "Development of Advanced Carbon Sorbents for CO_2 Capture" Krishnan, G.
- "Optimized Solvent for Energy-Efficient, Environmentally-Friendly Capture of CO_2 at Power Plants," Farthing, G.

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5. Malkov, S., Tikka, P., Gullichsen, J. "Towards Complete Impregnation of Woodchips with Aqueous Solutions." Part 1. http://lib.tkk.fi/Diss/2002/isbn9512261944/article1.pdf

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APPENDIX A

RESUMES OF KEY PROJECT MANAGER AND KEY PERSONNEL

SRIVATS SRINIVASACHAR, President Envergex LLC.

Research Areas of Expertise

- Expertise in energy and environmental engineering, power plant systems, and cross-industry products
- Current focus on identifying new business opportunities, setting vision, developing business plans, and implementing strategies for new products/processes
- Successfully executed projects for multiple clients with multi-industry, cross-functional, and international project teams – exceeding performance goals, ahead of schedule and with cost efficiency
- Strong experience in generating financing with industry and government
- Led product and process development groups. Managed large multi-contractor projects
- Obtained multiple patents and published over 50 technical papers

Education

2003-2004	Boston University, School of Management Boston, MA **Master of Business Administration**	
1981-1986	Massachusetts Institute of Technology MA **Sc.D. degree in Chemical Engineering**	Cambridge,
1976-1981	Indian Institute of Technology **Bachelor of Technology, Chemical Engineering**	Madras, India

Professional experience

Present ***President, Envergex LLC*** ***Sturbridge, MA***

- President

  Pursuing commercial production and supply of low cost and high performance activated carbon-based sorbents for mercury control. Working with partners to set up a venture for low-cost manufacturing of these sorbents.

  Continuing to develop and test formulations and treatment methods to maximize the performance of mercury sorbents for different coals and air pollution control system configurations

  Received from the US Patent and Trademarks office registration of trademark for mercury sorbents, ESORB-HG®, in March 2009 (Registration Number: 3589943)

  Manufactured and supplied commercial quantities and successfully demonstrated ESORB-HG® sorbent to several utility customers at full-scale, and responded to commercial bid requests for sorbent supply

Awarded a Small Business Innovation Research grant in June 2007 from DOE for a project for a novel method for reducing mercury re-emission from wet flue gas desulfurization (FGD) scrubbers.

Developed a business plan for coal and biomass to liquids venture to commercialize technology developed at a university

Teamed with University of North Dakota Energy & Environmental Research Center and a utility partner to perform process design, preliminary engineering, and plant capital and O&M costing to implement an innovative technology for activated carbon manufacturing integrated to a power plant

Developed a technical and business strategy to increase manufacturing process energy efficiencies at a major building materials company

1993 – 2006 ALSTOM Power, Inc./ABB Combustion Engineering, Inc.,Windsor, CT

- Technical Manager, Environmental Control Technology (March 2003-2006)
  Developed new product for control of mercury emission from coal-fired power plants. Set product strategy, positioned the differentiated product competitively, secured intellectual property, developed business plan, established partnership with component suppliers and external research organizations, led product development team, identified and successfully executed 3 commercial demonstration projects, scaled the product through laboratory, pilot and commercial scale, obtained industry, government and internal funding ($ 13 million)
- Principal Consulting Engineer, New Product Business Development (Oct. 1999 to March 2003)
- Environmental Group Leader, (Oct. 1997 – Sept. 1999)
  Minimizing pollutant emissions from a new gasification-based power plant technology
- Senior Consulting Engineer, (1994 – 1997)

1986-1993 Physical Sciences Inc. Andover, MA

- Manager, Environmental Remediation and Resource Utilization (1992-93)
  Directing R&D for an emerging business area. Negotiated with strategic partner for funding. Secured and managed an EPA Superfund project to remediate heavy metal-contaminated soils.
- Principal Research Scientist (1986-92)
  Principal Investigator on a multi-million dollar university-industry project. Created test methods and software for electric utilities to evaluate savings with various fuel switching options and predict fuel quality impacts on slagging and fouling in coal-fired power plants

Patents

U.S. Patent 6,848,374-Control of Mercury Emissions from Solid Fuel Combustion
U.S. Patent 6,749,681-Method of Producing Cement Clinker and Electricity
U.S. Patent 6,601,541-Method of Producing Steam and Calcined Raw Meal
U.S. Patent 6,089,171-Minimum Recirculation Flame Control Pulverized Solid Fuel Nozzle Tip
U.S. Patent 6,089,023-Steam Generator System Operation
U.S. Patent 5,556,447 and 5,245,120-Process for Treating Metal-Contaminated Materials

Selected Publication List

1. Benson, S.A., Crocker, C.R., Hanson, S.K., McIntyre, K.A., Just, B.J., Raymond, L.J., Pflughoeft-Hassett, D.F, Srinivasachar, S., Barry, L.T. and Doeling, C.M., "JV Task 115- Activated Carbon Production from North Dakota Lignite – Phase IIA," Final Report, U.S. Department of Energy Cooperative Agreement No. DE-FC26-98FT40321, June 2008
2. Kang, S.K., Srinivasachar, S. and Brickett, L.A., " Full-Scale Demonstration of Mer-Cure™ Technology for Mercury Emissions Control in Coal-Fired Boilers, " 31st International Technical Conference on Coal Utilization and Fuel Systems, Clearwater, FL May 2006
3. Srinivasachar, S. and Kang, S.K., "Field Demonstration of Enhanced Sorbent Injection for Mercury Control," DOE-NETL Program Review Meeting, July 2005, Pittsburgh, PA
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6. Liu, B.B., **Srinivasachar, S.**, and Helble, J.J., "The Effect of Chemical Composition on the Fractal-Like Structure of Combustion-Generated Inorganic Aerosols," Aerosol Science and Technology, 33(6), 459-469, 2000
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STEVEN A. BENSON, Professor of Chemical Engineering

Research Areas of Expertise

Dr. Benson's principal areas of interest and expertise include development and management of complex multidisciplinary research programs that are focused on solving environmental and energy problems associated with the utilization of renewable and fossil fuel resources. These programs include: 1) technologies to improve the performance of combustion/gasification and associated air pollution control systems; 2) transformations and control of trace elements in combustion and gasification systems; 3) carbon dioxide separation and capture technologies from combustion and gasification derived gases, 4) advanced analytical techniques to measure the chemical and physical transformations of inorganic species in gases; 5) computer-based models to predict the emissions and fate of pollutants from combustion and gasification systems; 6) advanced materials for power systems; 7) impacts of power system emissions on the environment; 8) harvesting diffuse energy resources; 9) national and international conferences and training programs; and 8) state and national environmental policy.

Education

Minnesota State University	Chemistry	B.S. 1977
Pennsylvania State University	Fuel Science	Ph.D. 1987

Professional Experience

2010 – present	Director, Institute of Energy Studies, University of North Dakota
2008 – present	Professor, Chemical Engineering, University of North Dakota
1999 – 2008	Senior Research Manager/Advisor, Energy & Environmental Research Center, University of North Dakota (EERC, UND).
1994 – 1999	Associate Director for Research, EERC, UND.
1991 – Present	President, Microbeam Technologies Incorporated.
1989 – 1991	Assistant Professor of Geological Engineering, Department of Geology and Geological Engineering, UND.
1986 – 1994	Senior Research Manager, Fuels and Materials Science, EERC, UND.
1984 – 1986	Graduate Research Assistant, Fuel Science Program, Department of Materials Science and Engineering, The Pennsylvania State University,
1983 – 1984	Research Supervisor, Distribution of Inorganics and Geochemistry, Coal Science Division, UND Energy Research Center
1979 – 1983	Research Chemist, U.S. Department of Energy Grand Forks Energy Technology Center, Grand Forks, North Dakota.
1977 – 1979	Chemist, U.S. Department of Energy ,Grand Forks Energy Technology Center, Grand Forks, North Dakota.

Synergistic Activities

- Senior Research Manager/Advisor Energy & Environmental Research Center, Dr. Benson was responsible for leading a group of about 30 highly specialized group of chemical, mechanical and civil engineers along with scientists whose aim is to solve problems on combustion and gasification system performance, environmental control systems, the fate of pollutants, computer modeling, and health issues for clients worldwide (PI on over $13 million).
- Current Research Support: "Advances in the Fundamental Understanding of Coal Combustion Emission Mechanisms", DOE EPSCoR IIP/ND EPSCoR , $2,500,000, 7/06 –

7/09; "Lignite Gasification Technology Summary Report", DOE and Lignite Energy Council, $100,000.

- Lignite Energy Council, Distinguished Service Award, Research & Development, 1997; College of Earth and Mineral Science Alumni Achievement Award, Pennsylvania State University, 2002; Lignite Energy Council, Distinguished Service Award, Research & Development, 2003; Lignite Energy Council, Distinguished Service Award, Government Action Program (Regulatory), 2005; Lignite Energy Council, Distinguished Service Award, Research & Development, 2008.
- Five Patent Applications: "Method and Apparatus for Capturing Gas phase Pollutant," 2005; "Removal and Recovery of Deposits from Coal Gasification Systems," 2007; Activated Carbon Production Plant," 2008; "Method for Improving Mercury Capture in Particular from Sulfur Bearing Gases," 2008; An Apparatus for Improving Water Quality by Means of Gasification, 2007.
- Provided testimony to the United States Senate Committee on the Environment and Public Works – Mercury emissions control at coal-fired power plants - 2008 and 2005.

Selected Topical Reports/Special Issues

- Controlling Mercury Emissions for Utilities Firing Lignites from North America, North Dakota Industrial Commission, 2007, 376 p.
- Air Quality: Mercury, Trace Elements, and Particulate Matter, Special Issue of Fuel Process. Technol.; Elsevier Science Publishers: Amsterdam, 2004, Vol. 85 (6–7), 423–499.
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Selected Recent Publications

- Azenkeng, A., Laumb, J.D., Jensen, R., Olson, E.S., Benson, S.A., and Hoffman, M.R., Carbene Proton Attachment Energies: Theoretical Study, *Phys. Chem. A* **2008,** *112,* 5269–5277.
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- Matsuoka, K.; Suzuki, Y.; Eylands, K.E.; Benson, S.A.; Tomita, A. CCSEM Study of Ash-Forming Reactions During Lignite Gasification. *Fuel* **2006**, *85*, 2371–2376.
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MICHAEL D. MANN, Professor and Chair of Chemical Engineering, Associate Dean for Research

Research Areas of Expertise

Dr. Mann's principal areas of interest and expertise include performance issues in advanced energy systems firing coal and biomass; renewable and sustainable energy systems with a focus on integration of fuel cells with renewable resources through electrolysis; production of fuel and specialty chemicals from crop oils; and development of energy strategies coupling thermodynamics with political, social, and economic factors. Dr. Mann is co-director of SUNRISE, UND's research group focused on the development and implementation of sustainable energy resources.

Education

Mayville State University	Chemistry, Mathematics	B.A., 1979
University of North Dakota	Chemical Engineering	M.S., 1981
University of North Dakota	Business Administration	M.B.A., 1987
University of North Dakota	Energy Engineering	Ph.D., 1997

Professional Expeience

2008	Interim Dean, School of Engineering and Mines, University of North Dakota
2006-*present*	Professor, Department of Chemical Engineering, University of North Dakota
2005-*present*	Chair, Department of Chemical Engineering, University of North Dakota
1999-2006	Associate Professor of Chemical Engineering, University of North Dakota
2000-2005	Director, Engineering Doctoral Program, University of North Dakota
1999-*present*	Senior Research Advisor, Energy& Environmental Research Center (EERC)
1994 – 1999	Senior Research Mgr, Advanced Processes and Technologies, EERC, UND.
1985 – 1994	Research Manager, Combustion Systems, EERC, UND.
1981 – 1985	Research Engineer, Wastewater Treatment and Reuse, EERC, UND

Selected Publications

- Hrdlicka, J.A., Seames, W.S., Mann, M.D., Muggli, D.S., and Horabik, C.A., "Mercury oxidation in flue gas using gold and palladium catalysts on fabric filters", *Engineering Science and Technology*, (2008), 42 (17), pp. 6677-6682.
- Bandyopahdyay, G.; Bagheri, F.M.; Mann, M.D.; "Reduction of Fossil Fuel Emission in US: A Holistic Approach Towards Policy Formulation" , *Energy Policy*; 2007, 35 (2) 950-965.

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- Mann, M.D.; Hajicek, D.R.; Henderson, A.K.; Moe, T.A. EERC Pilot-Scale CFBC Reveals Influence of Coal Properties. *Power Eng.* 1993, *97* (3), 33–37.

Patents

- 60/642,678 with Seames and D.S. Muggli, "Mercury Oxidation of Flue Gas using Catalytic Barrier Filters", January 2005.
- 5,546,875, "Controlled Spontaneous Reactor System", 1996 (method to upgrade properties of low-rank coals)
- 6,053,954, "Methods to Enhance the Properties of Hydrothermally Treated Fuels", 2000

APPENDIX B
Overall Project Budget and Budget Notes

The overall budget for the project through Budget Periods 1 (07/01/14-06/30/15) and Budget Period 2 (07/01/15 to 06/30/16) is shown below. A budget breakdown for the subcontractor costs is provided with their letter of commitment (Appendix C). The budget provides details for both the Federal (DOE-portion) and Non-Federal (NDIC/LEC-funded) portion. We are requesting a total of $50,000 from the NDIC/LEC over the two one-year budget periods. $25,000 each will be provided by ALLETE and SaskPower (letters attached in Appendix C). A budget justification sheet is also attached.

Envergex LLC Budget for E-CACHYS™ Project

	Category	Budget Period 1 (Federal) 07/14-06/15	Budget Period 1 (Non-Federal) 07/14-06/15	Budget Period 2 (Federal) 07/15-06/16	Budget Period 2 (Non-Federal) 07/15-06/16	Federal Total	Non-Federal Total
A	Personnel (Direct Labor)	77,490	11,716	92,250	11,716	169,740	23,432
	Fringe Benefits	25,699	3,885	30,594	3,885	56,293	7,771
	Total Direct Costs (Labor + Fringe)	103,189	15,601	122,844	15,601	226,033	31,202
C	Equipment					-	-
D	Travel	4,800		7,200		12,000	-
F1	Material and Supplies					-	-
F3	Consultants	3,000				3,000	-
F5	Subcontractor awards	324,953	25,003	295,084	24,977	620,037	49,980
G	Direct Costs (A thru F)	435,942	40,604	425,128	40,578	861,070	81,182
H	Indirect Costs	62,121	9,392	73,953	9,392	136,074	18,784
I	**Total Direct and Indirect Costs (G+H)**	**498,063**	**49,996**	**499,081**	**49,970**	**997,144**	**99,967**
J	Fee	1,500		900			

Budget Justification (Federal and Non-Federal)

Envergex LLC – Srivats Srinivasachar - PI

A. The Principal Investigator, Dr. Srivats Srinivasachar will devote 840 hours for federal funds and 127 hours for non-federal funds effort to the project for the 12 months duration in Budget Period 1 (07/01/14 to 06/30/2015). He will devote 1000 hours of effort for federal funds and 127 hours of effort for non-federal funds to the project for the 12 months duration in Budget Period 2 (07/01/15 to 06/30/2016).

B. The salary labor rate for Dr. Srinivasachar is $ 92.50 per hour. Fringe benefits are at 33.16% of salary labor rate.

C. Travel is estimated for 3 trips to University of North Dakota (Grand Forks, ND) from Sturbridge, MA for project execution related activities in Budget Period 1

D. Travel is estimated for 4 trips to University of North Dakota (Grand Forks, ND) from Sturbridge, MA for project execution related activities in Budget Period 2 and for 1 trip to DOE-NETL (Pittsburgh, PA) from Sturbridge, MA to provide project progress and results to DOE Project Manager

E. Labor overhead is at 28.57% of total direct costs (salary labor + fringe benefits)

F. General & Administrative costs are 24.60% of total direct costs + labor overhead

G. Indirect rates are applied on Envergex personnel labor costs only

H. $ 3,000 is allocated for Consultants (Ken Robinson – Mega-Carbon Company) for consulting on material agglomeration – letter attached for Budget Period

I. Non-Federal Funding of $99,967 will provided to the project via external funding. Non-federal funding support consists $25,000 from ALLETE Inc., $25,000 from SaskPower, and $50,000 from Lignite Energy Council. Letter of funding commitment are attached. $49,987 will be the share for Envergex.

J. Equipment and Supplies budget for BP1 and BP2 is provide in University of North Dakota budget details. Equipment ($60,605) and Supplies ($11,471) for BP1. Equipment (20,550) and Supplies ($9450) for BP2.

APPENDIX C
Letters of Commitment

THE INSTITUTE FOR ENERGY STUDIES
UPSON II ROOM 366
243 CENTENNIAL DRIVE STOP 8153
GRAND FORKS ND 58202-8153
(701) 777-2533
und.instituteforenergystudies@engr.und.edu

Dr. Srivats Srinivasachar
Envergex, LLC
10 Podunk Road
Sturbridge, MA

Dear Dr. Srinivasachar:

We are pleased to team with Envergex on this Phase II DOE SBIR/STTR application titled "High Capacity Sorbent and Process for CO_2 Capture" in response to DOE Funding Opportunity Announcement DE-FOA-0001072 to continue development of E-CACHYS™ technology. Work will be conducted by the University of North Dakota Institute for Energy Studies. Scope of the activities is summarized as follows:

Task 1 – Project management and planning

Task 2 – Laboratory-scale development of enhanced sorbent manufacturing methodology – UND will test methods of improving sorbent manufacturing. Performance of produced sorbents will be evaluated using existing lab-scale equipment at UND.

Task 3 – Laboratory-scale development of sorbent re-agglomeration methodology – UND will test methods to recycle sorbent fines that are generated during operation. UND will construct and install a test system as part of this task.

Task 4 – Evaluation of re-agglomerated sorbent performance and attrition characteristics – UND will determine the performance and flowability characteristics of the re-agglomerated sorbents in comparison to fresh sorbent that will allow for selection of optimum re-agglomeration methodology. Included in this task is construction and installation of an attrition test system that will provide an estimate of the sorbent particle size distribution as a function of a large number of cycles.

Task 5 – Modification of existing bench-scale slipstream facility – UND will design and incorporate modifications/additions/improvements to the existing bench-scale CACHYS™ facility that will allow for better utilization of E-CACHYS™ sorbents.

Task 6 – Production of sorbent for bench-scale testing – UND will produce a sufficient quantity of sorbent for bench-scale testing utilizing methods developed during Task 2.

Task 7 – Bench-scale testing – UND will perform testing on the modified bench-scale facility to optimize system parameters and establish the scaled-up performance of the E-CACHYS™ sorbent and process.

Task 8 – Economic analysis and development of commercial methodologies – Using the information gathered during previous tasks, UND will perform Aspen Plus modeling of the E-CACHYS™ process to determine the economic benefits of installing the technology at a coal-fired power plant. Included in this analysis is conceptual design of a full-scale facility and comparison to existing technology alternatives.

The cost of the effort is summarized in the attached budget.

Sincerely,

Steven A. Benson, Ph.D.
Director
Institute for Energy Studies

Daniel A. Laudal
Research Engineer
Institute for Energy Studies

FOR
Barry Milavetz, Ph.D.
Associate V.P. for Research
and Economic Development

High Capacity Sorbent and Process for CO_2 Capture

BUDGET:

University of North Dakota – Institute for Energy Studies

Unviersity of North Dakota
Budget

The budget detail is being submitted for proposal evaluation purposes only. Due to limitations within the university's accounting system, the system does not provide for accumulating and reporting expenses at the level of detail submitted. A budget summary is also presented in a format consistent with how costs will be accounted for and reported.

Category	Budget Period 1	Additional Funds	Budget Period 2	Additional Funds	Federal Total	Federal Total + Additional Funds
Personnel	133745	9233	140116	6638	273861	289732
Fringe Benefits	35422	2409	36969	1745	72391	76544
Travel	8119		10603		18722	18722
Equipment	60605		20550		81155	81155
Supplies	11471		9450		20921	20921
Construction						
Other	2800	6477	1800	9716	4600	20793
Subcontractor/Consultant Total						
Consultant A						
Consultant B						
Etc.						
Subcontractor/Consultant Total						
Total Direct Charges	252162	18118	219488	18099	471650	507867
Indirect Charges	72792	6885	75596	6878	148388	162151
TOTAL AWARD BUDGET	324953	25003	295084	24977	620038	670018

The indirect cost rate included in this proposal is the federally approved rate for the University of North Dakota. Indirect costs are calculated based on the Modified Total Direct Costs (MTDC), defined as the Total Direct Costs of the project less individual items of equipment $5,000 or greater and subcontracts in excess of the first $25,000 for each award.

***Additional funds** are funds that will be proposed to the the NDIC by Envergex, a letter of commitment was already secured. It is anticipated the request will be $100,000 split between UND and Envergex as additional funds to increase effort on the project.*

minnesota power
AN ALLETE COMPANY
Allan S. Rudeck, Jr., Vice President – Strategy & Planning

BNI COAL
AN ALLETE COMPANY
Wade Boeshans, General Manager - BNI

March 25, 2014

Dr. Srivats Srinivasachar
Envergex LLC
10 Podunk Road
Sturbridge, MA 01566-1046

Re: Support of Envergex and UND Phase II STTR proposal entitled "High Capacity Sorbent Process for CO_2 Capture"

Dear Dr. Srinivasachar:

ALLETE is pleased to support the Phase II STTR proposal from the Envergex LLC and UND to further demonstrate and test the E-CACHYS™ high capacity hybrid sorbents to capture CO_2 from coal combustion flue gases developed in the Phase I project. The Phase I project has shown that the E-CACHYS™ sorbents have CO_2 capacities twice as high as current CACHYS™ sorbents. This represents a quantum improvement from current technology and allows for significant decreases in capital and operating costs of the CACHYS™ CO_2 capture system, including steam usage for sorbent regeneration, parasitic power, and sorbent replacement costs. Current estimates for the cost of CO_2 capture is projected to be approximately $ 30/ton CO_2 for E-CACHYS™ compared to $ 36/ton CO_2 for CACHYS™, a 20% reduction.

We further understand that the work to further this technology concept will consist of bench-scale/slipstream testing, focusing mainly on the E-CACHYS™ sorbent development and evaluation, and complements the currently funded CACHYS program, which is focused on the process development component of the technology. This testing will be conducted on a slipstream system, currently installed at UND's coal-fired steam plant; so coal combustion-derived flue gas will be used to verify the potential of this carbon capture technology.

In January 2014, The Environmental Protection Agency (EPA) proposed rules for CO_2 emission from new stationary electric utility generating units. This action includes a standard of performance for new utility boilers and IGCC units based on partial implementation of carbon capture and storage (CCS) as the Best System of Emission Reduction (BSER). The rules include an emission limit for those sources is 1,100 lb CO_2/MWh. In June 2014, the EPA is expected to propose rules for existing utility coal-fired boilers. Developing low cost and high efficiency technologies for CO_2 capture is a key to meeting future CO_2 emissions targets.

ALLETE has a very strong interest in supporting the development and commercialization of the E-CACHYS™ technology. ALLETE is pleased to provide a total of $25,000 in cost-share for the two-year project, subject to project award by US Department of Energy and co-funding from the North Dakota

Industrial Commission. Upon successful completion of the Phase II STTR project, ALLETE would consider supporting larger scale testing of the E-CACHYS™ technology at one of its power plants.

If you have questions and require additional information, please contact Bill Sawyer at (218) 355-3580.

Sincerely,

Allan S. Rudeck, Jr.
Vice President – Minnesota Power

Wade Boeshans
General Manager - BNI

cc: Steve Benson, University of North Dakota

SaskPower
Powering the future

Asset Management, Generation
2901 Powerhouse Drive
Regina, SK S4N 0A1
Phone: (306) 566-2290
Fax: (306) 566-3348

2014 March 25

Dr. Srivats Srinivasachar
Envergex LLC
10 Podunk Road
Sturbridge, MA 01566

Re: Support of Envergex and UND Phase II STTR proposal entitled "High Capacity Sorbent Process for CO_2 Capture"

Dear Dr. Srinivasachar:

SaskPower is pleased to support the Phase II STTR proposal from the Envergex LLC and UND to further demonstrate and test the E-CACHYS™ high capacity hybrid sorbents to capture CO_2 from coal combustion flue gases developed in the Phase I project. The Phase I project has shown that the E-CACHYS™ sorbents have CO_2 capacities twice as high as current CACHYS™ sorbents. This represents a quantum improvement from current technology and allows for significant decreases in capital and operating costs of the CACHYS™ CO_2 capture system, including steam usage for sorbent regeneration, parasitic power, and sorbent replacement costs. Current estimates for the cost of CO_2 capture is projected to be approximately $ 30/ton CO_2 for E-CACHYS™ compared to $ 36/ton CO_2 for CACHYS™, a 20% reduction.

The goal of the technology to achieve 90 percent CO_2 removal aligns with the CO_2 reduction that is expected with our carbon capture project at Boundary Dam Unit 3 and what we expect to achieve with future carbon capture projects. In addition, we understand that this technology has a good likelihood of meeting the US DOE goal of increasing the current cost of electricity by no more than 35 percent, which represents considerable savings compared to conventional CO_2 control technologies.

Developing low cost and high efficiency technologies for CO_2 capture is a key to meeting future CO_2 emissions targets. The Canadian federal government has recently adopted regulations of CO_2 emissions from coal-fired electricity generation. Under these new requirements, coal-fired units built before 1975 will have to close by 2020 and units between after 1975 and 1985 will need to stop operating by 2030 — unless they are equipped with carbon capture and storage technology (CCS). This affects all but one of *SaskPower's* units, while the remaining unit would have to have CCS installed by 2042 or be retired.

Our understanding is that the work to further this technology concept will consist of bench-scale testing that is focused mainly on the E-CACHYS™ sorbent development and evaluation, and complements the currently-funded CACHYS™ program, that is focused on the process development component of the technology. This testing will be conducted on a slipstream system, currently installed at UND's coal-fired steam plant, so coal combustion-derived flue gas will be used to verify the potential of this carbon capture technology.

SaskPower has a very strong interest in supporting the development and commercialization of the E-CACHYS™ technology. *SaskPower* is pleased to provide a total of $25,000 in cost-share for the two-year project, subject to project award by US Department of Energy and co-funding from the North Dakota Industrial Commission. Upon successful completion of the Phase II STTR project, SaskPower would consider supporting larger scale testing of the E-CACHYS™ technology at one of its power plants.

Developing low cost and high efficiency technologies for CO_2 capture is key to meeting future CO_2 emissions targets. We believe that E-CASHYS™ technology has the potential to lead to a lower cost method to capture CO_2 from coal-fired systems. Therefore, *SaskPower* is pleased to provide a total of $25,000 in cost-share for the two-year project, subject to project award by US Department of Energy and co-funding from the North Dakota Industrial Commission. We recognize that further work is likely required at a larger scale to confirm the commercial viability of E-CACHYS™. In order to ensure its further development, *SaskPower* would consider supporting larger scale testing of the E-CACHYS™ technology at one of its power plants upon successful completion of the Phase II STTR project.

Please feel free to contact me if you have questions and require additional information.

Sincerely,

David W. Smith
Manager, Environmental Initiatives

cc. Blake Taylor
Director, Asset Management Generation

Steve Benson
Director, Institute for Energy Studies
School of Engineering and Mines
University of North Dakota