ALSTOM'S CHEMICAL LOOPING COMBUSTION TECHNOLOGY WITH CO_2 CAPTURE FOR NORTH DAKOTA LIGNITE UTILIZATION

Submitted to:

State of North Dakota
The Industrial Commission
State Capitol
Bismarck, ND 58505
Attn: Lignite Research Program

Amount of Request: $500,000

Submitted by:

Mr. Iqbal F. Abdulally
Dr. Shin G. Kang
Alstom Power Inc.
200 Great Pond Drive
Windsor, CT 06095

I. F. Abdulally

Mr. Iqbal F. Abdulally, Project Manager

Shin G K

Dr. Shin G. Kang, Critical Technology Manager
Boiler Combustion Systems
Alstom Boiler R&D Execution

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1 ABSTRACT

Alstom Power Inc. (Alstom) is developing a chemical looping process utilizing limestone as an oxygen carrier to transport oxygen from air to the fuel. This limestone-based chemical looping (LCL™) technology has the capability to capture CO_2 from new and existing coal-fired power plants while maintaining high plant power generation efficiency. The chemical and thermal looping technology can also be configured as a hybrid combustion-gasification process producing steam power or syngas or hydrogen for various applications while also producing a separate stream of CO_2 for use or sequestration.

Chemical Looping is a breakthrough "transformational" technology that has the potential of being the lowest cost electric power carbon capture and sequestration (CCS) option. The targets set by Alstom for this technology is to capture over 90% of the total carbon in the coal at cost of electricity which is less than 20% greater than conventional pulverized coal-fired or circulating fluidized bed units.

The basic concept of the chemical looping process is to replace the capital-intensive air separation unit (ASU) used in oxy-combustion with a solids oxygen carrier. The solids oxygen carrier reacts with the oxygen from the air in an Air Reactor which is then transported to a Fuel Reactor where it releases the delivered oxygen for combustion (or gasification) of a carbonaceous fuel. A product gas containing high CO_2 content is produced that can be further processed for sequestration or utilization for high purity CO_2 products.

Alstom herein proposes a program to test and commercially develop a limestone-based chemical looping combustion process (LCL-C™) to utilize partially dried (dried to 25-30% moisture) and run-of-mine North Dakota lignite. The dried North Dakota lignite will be supplied by Great River Energy for both bench-scale and pilot-scale tests. This grant application to NDIC proposes to add a test campaign to Alstom's project titled, "Alstom's Chemical Looping Combustion Technology with CO_2 Capture for New and Retrofit Coal-fired Power Plants" (DOE/NETL Cooperative Agreement No. DE-FE0009484). The DOE/NETL recently provisionally awarded Phase II with definitization of the award to occur during October 2013. Under this grant, North Dakota lignite will be evaluated through comprehensive 3 MW_{th} LCL-C™ Prototype parametric testing.

This proposed work would address potential operational issues or benefits unique to North Dakota lignite (e.g., high-sodium, high-moisture contents), optimize the chemical looping process design and operating conditions, and provide information needed to evaluate and demonstrate the use of North Dakota lignite for chemical looping combustion at a larger scale. By testing dried North Dakota lignite from Great River Energy, the work would also evaluate the benefit of pre-drying North Dakota lignite. Specific technical objectives include:

- Obtain design information such as solids behavior and heat transfer for both reactors under various operating parameters,
- Optimize and determine the best product gas quality (composition) and highest thermal efficiency,
- Identify emissions of major gas and hazardous air pollutant (HAP) species, and
- Optimize operating parameters for North Dakota lignite.

In this proposed North Dakota lignite test program, Alstom teams up with Great River Energy. Great River Energy will provide dried North Dakota lignite for testing at Alstom's 3-MWth test facility as well as industrial perspective in the product development.

<u>In this proposal, Alstom requests $500,000 from the North Dakota Industrial Commission for the added North Dakota lignite scope.</u> The total cost estimate for the added scope is $625,000. Alstom is committed to provide 20% of the cost as cost-share. The budget estimate for the base DOE/NETL-sponsored Alstom program PLUS the North Dakota lignite coal test is $10,489,821. The DOE/NETL cost share is $7,891,857 with Alstom, State, and industry providing the balance cost share (NDIC cost share is 4.8%).

2 PROJECT SUMMARY

Alstom Power Inc. (Alstom) is applying to the North Dakota Industrial Commission (NDIC) for a grant of $500,000 for a 36-month program to test and develop a limestone based chemical looping combustion (LCL-C™) process that can utilize North Dakota lignite. LCL-C™ process is one of the lowest cost options for coal-based power generation while capturing carbon for sequestration or utilization. Through recent extended operation of the 3-MWth test facility (see Figure 1) in a self-sustained mode,

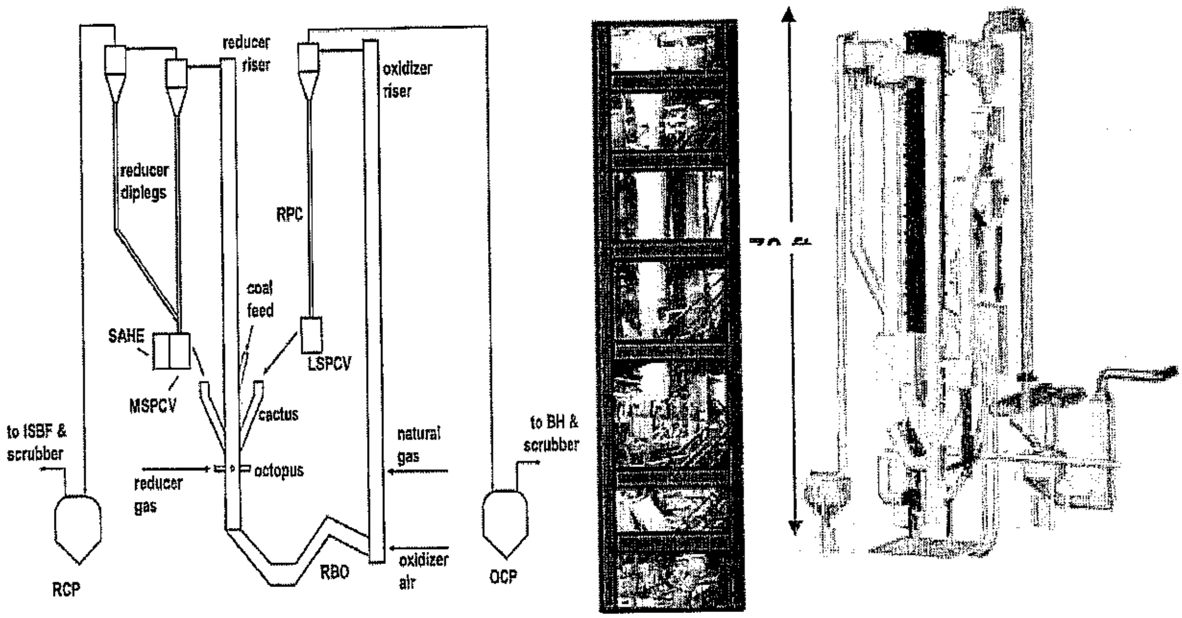

Figure 1 Details of 3 MWth Prototype Model

Alstom has successfully demonstrated the technical feasibility and scalability of the LCL-C™ process. As the next step for further development, Alstom proposed to the Department of Energy (DOE) an extensive program designed to address product and technical gaps identified in a DOE/NETL-sponsored Phase I program, optimize the LCL-C™ process and prepare for a larger-scale demonstration. The 36-month, multi-partner program has recently been provisionally awarded by the DOE/NETL. The scope and budget details will be defined in October 2013.

In this grant application to NDIC, Alstom proposes to include a scope in the $10 million DOE program and address knowledge gaps specifically in utilizing North Dakota lignite coals for LCL-C™ process. North Dakota lignite coals have relatively high moisture and sodium contents. Potentially, this unique fuel property has both beneficial and adverse effects on the LCL-C™ design and performance. The high moisture could cause fuel handling difficulties while high sodium could result in agglomeration of ash in the LCL-C™ reactors disrupting solids flow. On the other hand, high moisture promotes fuel conversion through steam gasification and high sodium also catalytically enhances carbon gasification reaction as well as limestone (oxygen carrier) utilization. Many of the challenges in utilizing coals, and North Dakota lignite, in particular, are overcome by employing pre-drying processes such as that of Great River Energy. The overall impact of the North Dakota lignite properties and the benefit of pre-drying it, however, need to be fully understood for its future utilization in the LCL-C™ process.

Under this grant, North Dakota lignite (both dried and run-of-mine) will be thoroughly evaluated through comprehensive parametric testing both in a 4-inch bubbling bed reactor and in a 3 MW_{th} LCL-C™ prototype. A one-week, round-the-clock test campaign designed specifically for North Dakota lignite fuels will be executed at the prototype facility. (See Figure 1 for details of the prototype.) This proposed work would optimize the chemical looping process design and operating conditions, and provide information needed to evaluate and demonstrate the use of North Dakota lignite for chemical looping combustion at a commercial scale. By testing dried North Dakota lignite from Great River Energy, the work would also evaluate the benefit of pre-drying North Dakota lignite. Specific technical objectives of the proposed work include:

- Obtain and analyze information for the design of LCL-C™ reactors under various operating conditions while firing North Dakota lignite fuels at the 3-MWth prototype test facility,
- Optimize and determine the best product gas quality and highest thermal efficiency
- Identify emissions of major gas and HAP species, and
- Optimize operating parameters for North Dakota lignite.

As mentioned above, the scope with North Dakota lignite is proposed as part of a larger LCL-C™ development project selected for an award under DOE/NETL Advanced Oxy-combustion program. The 10 million USD Phase II program is a continuation of the recently completed Phase I DOE/NETL project and will have a 36-month performance period starting from October 2013. The team members include Great River Energy, Jamestown Board of Public Utilities, Harris Group Illinois Clean Coal Institute, University of British Columbia, Carmeuse Lime and Stone, and Zenz Consulting. The overall objectives of the revised Phase II project are to:

- Conduct a series of tests on the 3-MW_{th} prototype to address technical gaps identified in Phase I (techno-economic analysis of the process) and
- Develop a design of commercial-scale LCL-C™ plants.

The Phase II program will include parametric testing at the 3-MW_{th} test facility, engineering and 3-D computational fluid dynamics (CFD) modeling tools along with techno-economic analysis. The revised scope of testing no longer includes testing with different fuel types. This proposal to NDIC will add a test campaign firing partially dried (dried to 25-30% moisture) and run-of-mine North Dakota lignite allowing expanding the knowledge base and performance database. Detailed measurements addressing changes in furnace heat absorption, ash deposition, material corrosion, combustion and pollutant formation will be obtained. Test results will be used to evaluate and improve modeling tools for LCL-C™ and provide information needed to effectively take the next step to demonstrate this technology in a large scale field validation facility.

3 PROJECT DESCRIPTION

3.1 Introduction

Over the past decade or so, Alstom has been developing chemical looping technology, a promising "game-changing" breakthrough power generation technology for CO_2 capture and sequestration while utilizing coal and opportunity fuels. Alstom's recent proposal to the US Department of Energy (DOE) titled "Alstom's Chemical Looping Combustion Technology with CO_2 Capture for New and Retrofit Coal-fired Power Plants" was provisionally awarded. The scope and budget will be finalized in October 2013. The DOE/NETL project includes a diverse group of partners and funding sources: Great River Energy, Jamestown Board of Public Utilities, Illinois Clean Coal Institute, Carmeuse Lime and Stone, University of British Columbia, and Zenz Consulting.

In the revised scope, testing with additional coals is no longer included under this DOE/NETL funded effort. In this grant application to NDIC, Alstom proposes to add a scope to the DOE program and address knowledge gaps specifically in utilizing North Dakota lignite coals for LCL-C™ process. Great River Energy operates a lignite drying system at their Coal Creek station and has expressed interest in providing dried lignite and in-kind co-funding for an additional test campaign for this DOE Advanced Oxy-combustion Phase II project. It would be advantageous to leverage NDIC and Great River Energy funding by incorporating chemical looping prototype testing of dried and run-of-mine North Dakota lignite firing into the DOE project.

Chemical looping combustion of dried lignite in the 3 MW_{th} prototype facility under optimum conditions is expected to give the desired specification of the product gas from the Reducer. Factors such as impurities in the coal may significantly influence performance and operation. If too excessive, impurities such as sodium affect ash agglomeration and fouling behavior, strongly impacting negatively Reducer operation, heat transfer and overall LCL-C™ and steam generator performance. On the other hand, a small amount of sodium has been known to catalytically accelerate gasification reactions of carbonaceous fuels, potentially reducing the required reactor volume for high conversion of fuels. The dried lignite will also generate a different Reducer product gas quality and influence reactor sizing based on the residence time needed for completed carbon conversion compared to run-of-mine or as-received lignite. Testing with dried and run-of-mine North Dakota lignite will allow evaluation and optimization of operating conditions and indicate the optimum drying requirements for this fuel.

This proposed work would optimize the chemical looping process via operating conditions, LCL-C™ reactor and steam generator designs and provide information needed to evaluate and demonstrate the use of dried North Dakota lignite. Specific objectives of the proposed test campaign for North Dakota lignite include:

- Obtain information for the design of both reactors under various operating conditions,
- Optimize and determine the best product gas quality and highest thermal efficiency
- Identify emissions of major gas and HAP species, and

- Optimize operating parameters for North Dakota lignite.

The cost estimate for the proposed work is $625,000. In this proposal, Alstom requests $500,000 from the North Dakota Industrial Commission for the added North Dakota lignite scope. Alstom is committed to provide 20% of the cost as cost-share. If the proposal is accepted, this additional scope will be rolled into the DOE/NETL-sponsored three-year Phase II project currently with $9,864,821 of funding. The DOE has committed $7,891,857 with Alstom and other team members providing the balance cost share.

3.2 Concept of LCL-C™ Process and Development History

The basic chemical looping concept uses solids oxygen carrier to replace a capital-intensive Air Separation Unit (ASU) used in oxy-combustion and produce flue gas of mainly CO_2 and water vapor, which can be dried, compressed, and purified for sequestration or enhanced oil or gas recovery. Figure 2 shows a schematic diagram of a chemical looping combustion process, where two CFB reactors are interconnected to form a loop. In the air reactor, a solid oxygen carrier picks up oxygen from air through oxidation reaction and leaves nitrogen behind. This chemical reaction is exothermic and releases heat into the air reactor.

The hot oxygen-carrying solid carrier is then transported to a fuel reactor, where it releases its oxygen under chemically reducing conditions. The released oxygen then converts the coal stream in the fuel reactor into combustion gases. CO_2 is removed from this stream analogous to oxy-combustion. The solid carrier also carries heat that is needed for conversion of the fuel. After release of heat and oxygen in the fuel reactor, the solid oxygen carrier is then recycled back to the air reactor for regeneration. The solid carrier continues to circulate between the two reactors realizing a "chemical loop." Another loop can be incorporated to produce hydrogen.

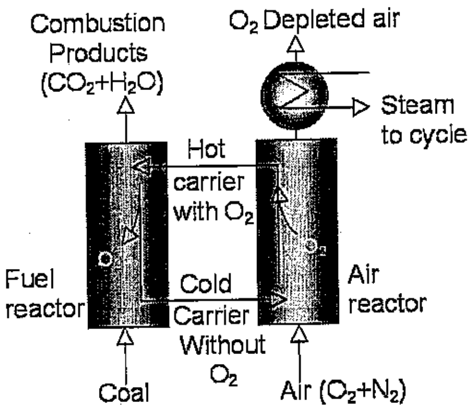

Figure 2 Schematic diagram of a chemical looping process

Alstom's chemical looping technologies commenced in 1997 building on knowledge and experience in Circulating Fluidized Bed (CFB) and entrained gasification. In chemical looping, the choice of solid oxygen carriers dictates the design, performance and, importantly, the economics of the overall chemical looping combustion process. Recognizing this, Alstom has thoroughly evaluated and screened a number of oxide/sub-oxide systems in terms of their cost, commercial availability, oxygen carrying capacity, attrition behavior, toxicity, transport properties, and attrition behavior. Limestone was finally selected as the choice of material for carrying oxygen. Limestone offers various advantages – it is abundant and low in cost; its chemistry in the LCL-C™ process is very similar to that in commercial CFB boilers; and the materials found in the LCL-C™ process (CaO, $CaSO_4$, $CaCO_3$) are also commonly present in CFB boilers. Also the supply chain network of the raw material (limestone) and the byproduct (gypsum) is well developed throughout the world. Further, limestone utilization in a LCL™ power plant will be the same as is used today in commercial CFB power plants.

Since the selection of the oxygen carrier, the LCL-C™ process development has progressed through four phases of collaboration between Alstom and DOE/NETL. The developmental activities were carried out in a systematic manner at various scales in order to verify the feasibility of LCL-C™ process. Bench-scale activities included TGA studies for solids oxygen carrying capacity, drop tube furnace studies for reactivity determination, and finally 65-kWth process development unit (PDU) operation for an integrated system operation and test validation. Cold flow modeling activities with 40-ft setup was instrumental in understanding solids behavior in a chemical loop system. The project development effort is currently in a 3-MWth prototype testing phase. This 3-MWth prototype located at Alstom's Power Plant Laboratories in Windsor, Connecticut, is the first chemical looping unit in the World to achieve auto-thermal chemical looping operation for over 52 hours with and aggregate operating time of over 350 hours. Although there are some bench non-autothermal bench scale studies involving PDU less than 140 kWth using metal oxide solids oxygen carriers and many studies to develop engineered metal oxide solids oxygen carriers, Alstom is the only OEM demonstrating relative inexpensive limestone base chemical looping at pilot scale.

3.3 Technical and Economic Feasibility of LCL-C™ Process

Our research and development efforts thus far have demonstrated that the LCL-C™ process is both technically and economically feasible. As mentioned in the previous section, Alstom has conducted extensive experimental testing at various scales. Recent validation activities have been at a 3-MWth Prototype facility, which has been operated for an aggregate of over 350 hours and finally achieving 40 hours of "continuous" autothermal operation in May 2013. The autothermal operation of the Prototype clearly confirms most of the chemical reactions that enable the overall LCL-C™ process at a 3-MWth scale proving that the LCL-C™ process is technically feasible and that the process can be scaled up further.

As far as economic feasibility is concerned, Alstom has executed several reference plant studies where the economic comparison was made between the chemical looping process and other carbon capture technologies. In the recently completed Phase I project (DOE/NETL Cooperative Agreement No. DE-FE0009484), Alstom has reconfirmed that the chemical looping process is the lowest cost option for power generation while capturing carbon. More specifically, Alstom completed a techno-economic analysis of four (4) LCL-C™ configurations: (1) atmospheric pressure LCL-C™ system using transport reactors for both the Oxidizer and Reducer (see Figure 3), (2) a LCL-C™ system with the Reducer reactor only operating in the CFB mode, (3) a LCL-C™ system with an advanced ultra-supercritical steam cycle, and (4) a pressurized LCL-C™ system with an advanced ultra-supercritical steam cycle. A fifth LCL-C™ case (Case 4a) was made during the sensitivity study that was identical to Case 4 except at a Reducer pressure of 3 atm instead of 7 atm. These cases were compared against the DOE's baseline reference SCPC case (Case 11) without CO_2 capture and with the DOE's oxy-combustion reference SCPC (Case 5C).

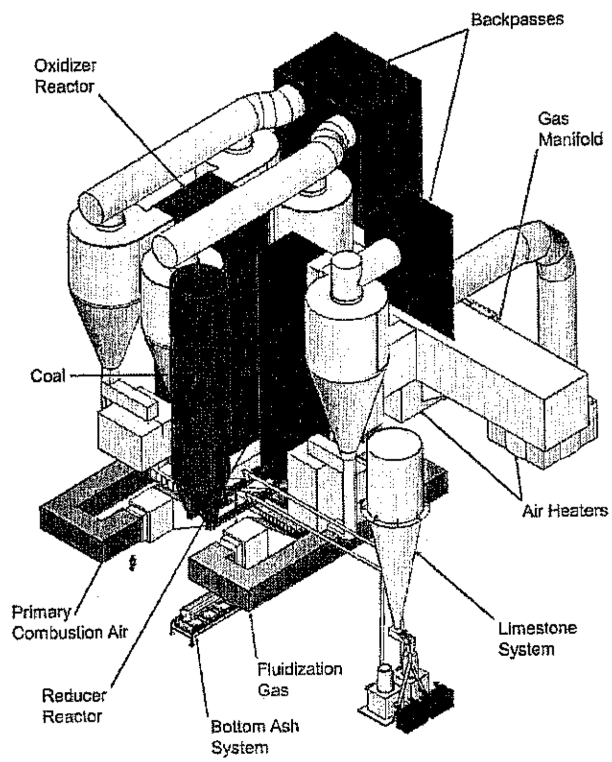

Figure 3 Illustration of the 550MWe LCL-C™ Conceptual Plant

The major findings from the Phase I study are as follows.

- LCL-C™ technology fully meets the DOE goal of at least 90% CO_2 capture at a cost of electricity (COE) less than a 35% increase without transportation and storage relative to a conventional coal-fired plant without CO_2 capture. All of the atmospheric pressure LCL-C™ cases had at least 97% CO_2 capture, while the pressurized case had 95.9% CO_2 capture.
- All of the LCL-C™ cases had COE increases less than 20%, which meets the Alstom's goal of a COE increase less than 20%. LCL-C™ technology compared very favorably with the DOE oxy-PC, which had 93% CO_2 capture at a COE increase of 53.5%.

- The 3 atm pressurized LCL-C™ case evaluated best in the sensitivity study of economic performance of all the LCL-C™ cases, with a COE Increase of only 16.9% relative to the SCPC without CO2 capture. This case takes advantage of the performance benefits of going to advanced steam conditions and elevated Reducer pressures while avoiding the added costs associated with having a very tall solids pressure seal (as in the 7 atm Case 4).
- The CO_2 Avoided Cost was 24.2 to 27.0 \$/ton CO_2 for the four LCL-C™ cases, while the CO_2 Captured Cost was between 24.7 and 28.8 \$/ton CO_2. This is slightly higher than Alstom's target of 20 \$/ton CO_2, which should be achievable with further optimization. The LCL-C™ performance again compares favorably with the CO_2 Avoided Cost and CO_2 Captured Cost of 79.3 \$/ton CO_2 and 57.6 \$/ton CO_2, respectively, for the DOE oxy-PC case.
- The net plant efficiency for the atmospheric SC LCL-C™ cases was only 3.5% points less than that for the DOE SCPC without CO_2 capture, which is equivalent to an 8.9% energy penalty. An energy penalty of less than 10% is very good and compares favorably with the 25.4% energy penalty for the DOE oxy-PC case. The energy penalty for the two A-USC LCL-C™ cases are actually negative as the net plant efficiencies are 1.8 - 3.4% points greater than the DOE SCPC without capture case, despite achieving at least 95.9% CO_2 capture.
- The auxiliary power requirements for the LCL-C™ cases range from 11.5% to 18.1% of the net power as compared to 5.5% for the DOE SCPC without CO_2 capture. This increase is largely due to the added power requirements to compress the CO_2 up to 15.3MPa (2,215 psia). The LCL-C™ auxiliary power requirements compare favorably with the DOE oxy-PC case, which required 43.1% of the net power – including 126,680kW just for the air separation unit. Eliminating the ASU by using solid oxygen carriers is a key LCL-C™ enabler for reducing auxiliary power requirements and improving net plant efficiency.
- The atmospheric pressure LCL-C™ boiler island is compact as compared with a comparable output SCPC or CFB boiler island. The height of the

atmospheric pressure LCL-C™ boiler is about 30% less than a PC and 13% less than a CFB.

- Water usage is similar or less than the SCPC without CO_2 capture for all LCL-C™ cases. Raw water withdrawal is only 2% greater for the SC LCL-C™ Cases 1 and 2 and up to 30% less for the A-USC LCL-C™ cases 3 and 4.This compares favorably with the oxy-PC case, which had 29% greater than the SCPC without CCS.

3.4 Technical Approach and Work Plan

In this section, the technical approach and work plan for the project to be executed are presented. In order to give an overview of the current and upcoming effort for the process development, the technical approach and work plan defined in the DOE/NETL Phase II proposal selected by the DOE (and redefined during negotiation) are presented verbatim. The additional scope proposed to the NDIC specifically for North Dakota lignite fuels is presented underlined and in blue fonts. Incidentally, the Phase I project (Budget Period 1) has been just completed and the Phase II project will start in October and be executed in three one-year budget periods (Budget Periods 2, 3, and 4) over 36 months.

3.4.1 Objectives

The overall project objective is to advance the development of Limestone Chemical Looping Combustion (LCL-C™) technology through extensive prototype testing. The technology is a promising option for generating power from coal while achieving greater than 90% carbon capture and increasing the cost of electricity by no more than 35 % compared to a new supercritical pulverized coal plant.

Phase II efforts shall be directed towards validating the improvement ideas and concepts generated in Phase I through implementation and testing in a 3 MWth LCL-C™ Prototype plant. The LCL-C™ based commercial system developed in the Phase I effort shall be refined based on the results from the Prototype testing and optimization. The specific objectives of Phase II are as follows:

1. Optimize and improve the LCL-C™ design and process through a series of parametric tests on the 3-MWth prototype
2. Design a commercial LCL-C™ product design

3.4.2 Scope of Work

Phase II will build upon knowledge gained in Phase I with the 3 MWth LCL™ Prototype facility and utilize the results of the technology gap and techno-economic analyses to accomplish the Phase II objectives.

Budget Period 2 (BP2) [the first budget period of the program]

BP2 starts in October 2013. Components of the 3 MWth Prototype shall be redesigned and modified to address the high priority technology gaps and current limitation of the LCL-C™ system. An initial characterization test program will be performed in the early part of the BP2 (before the planned relocation of the facility). These tests will be used to determine modifications that will help obtaining and analyzing broad sets of data, solids and gas samples. The more important modified components shall be reinstalled on the 3 MWth Prototype during the scheduled relocation of the Recipient's test facilities. It is envisaged that some other modification will be done after testing outlined in Budget Period 3.

The existing 40-foot cold flow model (CFM) shall be utilized to support modifications to the prototype including tests of the Reducer bottom outlet (RBO) gate, the DipLeg gas drain; and tests for solids transport stability and control. Computational fluid dynamics (CFD) modeling of the solids transport shall be conducted to support solids transport testing. Bench scale testing, mainly utilizing Thermo Gravimetric Analysis (TGA) and a 4-inch Bench Scale Test Facility (BSTF), shall be conducted to quickly evaluate various operating scenarios. The Recipient's 4-Inch BSTF shall be commissioned to facilitate cost effective bench scale testing of LCL-C™ process improvements in support of the 3 MWth LCL-C™ Prototype development efforts. Calcium chemistry shall be studied for more detailed understanding of the limestone transformation in the LCL-C™ system. Analytical techniques for quantifying spatial distributions of calcium species within solid particles shall be developed. Bench-scale tests will be conducted to evaluate the effect of the North Dakota lignite fuel property (high sodium and high moisture) on the LCL-C™ design and performance.

Budget Period 3 (BP3)

The Recipient shall complete the remaining Prototype component modifications and installation in the Prototype facility. Prototype testing shall address technology gaps identified in Phase I impacting operability and performance. In particular the following gaps shall be addressed in BP2 & BP3:

Technology Gaps (1-9)

1. High Solids Loss from Reducer Loop
2. Main DipLeg Flushing
3. Stability of Solids Circulation
4. Oxygen Carrier (Sorbent) Activation
5. Sulfur Management
6. Low Reactor Temperatures
7. Carbon Carryover
8. Condenser and Baghouse
9. Product Gas Recycle

The objective is to achieve a smoothly running Prototype facility capable of completing relatively trouble-free performance over a wide range of operating conditions and loads. Also a dedicated one-week, round-the-clock test campaign will be executed specifically to fire North Dakota lignite fuel in the 3-MWth prototype test facility.

Solids transport testing with the existing 40-foot CFM shall be used to support Prototype operations and to investigate scale-up to a reliable 10 to 25 MWe field validation. CFD modeling shall continue to be used to address solids transport phenomena such as quantifying mixing and distribution of multiple solid phases in the inventory. There shall be opportunities to validate the CFD analyses with Prototype test data.

Bench scale testing using the BSTF, drop tube furnaces, and 4" fluid bed reactor shall be used to support Prototype testing. Analysis of limestone materials shall be conducted before prototype testing. The BSTF shall be used to address reaction chemistry issues (e.g. sulfur capture, sorbent activation, carbon conversion, etc.). The pressurized thermo-gravimetric analyzer system with a mass spectrometer shall also be employed to assist in sorbent characterization studies.

Budget Period 4 (BP4)

Prototype testing shall address technology gaps identified in Phase I impacting operability and performance. The development of the 550 MWe LCL-C™ product design shall be further advanced based on lessons learned from the bench and prototype testing planned under Phase II, and the challenges and gaps identified during the design of the 550MWe net LCL-C™ plant for the Phase I. As needed, bench-scale testing will be conducted to address any other technology gaps. A techno-economic analysis for the design will be updated including consideration of the results and analysis in reevaluating the Technology Gaps.

3.4.3 Tasks to be Performed

Task 1.0 – Project Management and Planning (BP2, BP3, and BP4)

The Recipient shall manage and direct the project in accordance with a Project Management Plan to meet all technical, schedule and budget objectives and requirements. The Recipient shall coordinate activities in order to effectively accomplish the work. The Recipient shall ensure that project plans, results, and decisions are appropriately documented and project reporting and briefing requirements are satisfied.

The Recipient will update the Project Management Plan as necessary to accurately reflect current status of the project. Examples of when it may be appropriate to update the Project Management Plan include: (a) project management policy and procedural changes; (b) changes to the technical, cost, and/or schedule baseline for the project; (c) significant changes in scope, methods, or approaches; or, (d) as otherwise required to ensure that the plan is the appropriate governing document for the work required to accomplish the project objectives.

Management of project risks shall occur in accordance with the risk management methodology delineated in the Project Management Plan in order to identify, assess, monitor and mitigate technical uncertainties as well as schedule, budgetary and environmental risks associated with all aspects of the project. The results and status of the risk management process shall be presented during project reviews and in Progress Reports with emphasis placed on the medium- and high-risk items.

Task 2.0 – Prototype Engineering, Modification and Testing (BP2, BP3, and BP4)

Based on the identified gaps and the operational experience, efforts shall be made to further modify the prototype to improve equipment design and function with the objective of optimizing the process. Extensive parametric testing shall then be conducted to provide a substantial amount of experience and knowledge base which shall then be used to improve design and scale up the LCL-C™ process to a field validation or demonstration scale unit.

Subtask 2.1 - LCL-C™ Prototype Engineering, Modification, and Testing (BP2)

The Recipient shall complete engineering for equipment modification of the Prototype and product gas recycling equipment as well as designing the test matrices, analyzing the test data and determining the need for further performance improvements and system modifications required to meet performance objectives. Modifications to the test facility are proposed to improve fuel conversion, gas product quality, and to ensure a stable and flexible operation under all parametric conditions. Known modifications include the Reducer Cactus/Octopus, reducer bottom outlet (RBO) design, RBO Gate; sealpot design gas venting in dipleg, and cyclone system. These modifications are expected to improve carbon conversion and sulfur retention either by keeping the solids in the system longer, or by controlling gas-solids chemistry (stoichiometry) tighter. Engineering for automatic control of solids transport system shall also be accomplished. Engineering and installation for controls sensors for measuring solids flows and levels in the DipLegs and RPC shall be accomplished for use in the Prototype and the 40-foot LCL-C™ CFM. These sensors shall enhance the ease of solids inventory control. High-speed pressure sensors shall also be tested on the CFM to support prototype testing. These are expected to produce useful performance and solids control data.

Subtask 2.2 - Prototype Operability Tests (Technology Gaps 1 to 9) (BP3)

This group of tests is intended to apply lessons learned, remedy current operability and performance shortfalls (Technology Gaps 1 to 9) recognized during previous testing and during the Phase I Technology Gap Analysis. Prototype modifications shall be completed. The subtask is intended to result in a smoothly running facility generally capable of completing relatively trouble-free performance over a wide range of operating conditions and loads. Test includes completing work to limit carbon carry-over from the Reducer to the Oxidizer. The RBO Gate was installed before the recent 40-hr autothermal testing in order to damp out uncommanded changes in Reducer/Oxidizer stoichiometry which can in turn cause waves of high CO and sulfur emissions. Evaluation of its performance shall continue. Decreasing CO and sulfur emissions in the Reducer over a wide operating range should also be aided by commissioning a Sorbent Activation Heat Exchanger (SAHE) to enable operation of the Sorbent Activation system. Also included is development testing to eliminate Dipleg flushing caused by product gas generated in the Dipleg during coal firing. The Dipleg gas drain is intended to accomplish this objective as well as make operation of the SAHE during coal-firing. This change, along with a solids transport control system, is expected to benefit solids transport stability as well as decrease CO and sulfur emissions. Also, a test campaign firing North Dakota lignite will be added to this budget period to study the effect of changes in coal properties on the overall performance. Run-of-mine North Dakota lignite and lignite dried at the Great River Energy by their pre-drying technology and supplied to Alstom will be fired in a one-week, round-the-clock test campaign in this budget period. The test program will be designed to obtain understanding of the effect of sodium and moisture as well as drying on the overall performance of LCL-C™ process. Major gas species and trace element emissions will be measured using gas analysis system. Special sampling trains for obtaining solid samples will be used.

Subtask 2.3 - Prototype Operability Tests (Technology Gaps 1 to 9) (BP4)

The subtask is a continuation of Subtask 2.2 activities. This group of tests is intended to apply lessons learned, remedy current operability and performance shortfalls (Technology Gaps 1 to 9) recognized during previous testing and during the Phase I Technology Gap Analysis. Testing will be conducted to ensure good carbon conversion in the system. The data and samples from the test campaign firing North Dakota lignite executed in BP2, 3 & 4 will be analyzed during this period.

Task 3.0 - Process Refinement and Prototype Testing Support (BP2, BP3, and BP4)

The Recipient shall complete research and development of solids transport phenomena to support stable LCL-C™ operation and scale-up to a field validation facility demonstration. Cold flow modeling and multi-phase CFD modeling shall be conducted to address this issue. Some of the LCL-C™ chemistry shall be reviewed further in a well-controlled environment to ensure development of a robust sulfur management strategy.

Subtask 3.1 – Process Refinement in support of Prototype modifications (BP2)

Solids Transport Testing. The existing 40-foot CFM shall be utilized to support modifications to the prototype including tests of the RBO Gate, the DipLeg Gas Drain; and tests for solids transport stability and control. Testing shall be conducted to separate carbon from the solids inventory as a way of improving fuel conversion.

Multi-phase Computational Fluid Modeling. CFD tools such as Fluent® and Barracuda® shall also be employed to supplement development effort of a robust solids transport and control system. These tools shall be used for quantifying mixing and distribution of multiple solid phases in the inventory. CFM test data shall be used to validate CFD analyses.

Bench-scale Tests. This subtask includes small-scale testing in a well-controlled chemical and thermal environment to evaluate various operating scenarios. A quick screening of various limestone samples shall also be conducted before prototype testing.

To support pressurized LCL-C™ development, the Recipient's pressurized thermo-gravimetric analyzer system with a mass spectrometer shall also be employed to assist characterization studies. The Recipient's LCL-C™ 4 Inch BSTF shall be commissioned (by converting the Recipient's 4 Inch bench-scale CFB) for use during BP3. This bench facility allows cost effective bench scale testing of LCL-C™ process improvements in support of the 3 MWth LCL-C™ Prototype development effort. In this budget period, the North Dakota lignite samples will be tested in the thermo-gravimetric analyzer and the 4-in bubbling bed reactor for initial characterization of the fuels. For this effort, the 4-in bubbling bed reactor will be modified to allow fluidization study at a high temperature. Focus will be placed on (i) potential agglomeration of the ash and oxygen carrier due to presence of sodium in the fuel and (ii) potential catalytic effect both on the carbon conversion and the utilization of the limestone oxygen carrier. Agglomeration may significantly affect the solids transport behavior of oxygen carriers.

On the other hand, the catalytic effect may potentially reduce the reactor size and consumption of the oxygen carrier.

Sample Analysis and Characterization. Chemical and physical analysis of various samples generated from previous Prototype testing shall be carried out in this subtask. Limestone transformation, both chemical and physical, in the LCL-C™ system shall be investigated in detail. Analytical techniques for quantifying spatial distribution of calcium speciation within solid particles shall be developed. The Recipient shall also quantify various calcium species using analytic techniques. Data from prototype and bench scale testing shall be reduced and analyzed. Samples to be generated from the prototype and the bench-scale testing shall be analyzed and characterized for performance evaluation.

Subtask 3.2 – Process Refinements in Support of Prototype Operational Testing. (BP3)

Solids Transport Testing. The existing 40-foot CFM shall be utilized to support Prototype operating difficulties and for operator training on the new configuration.

Multi-phase Computational Fluid Modeling. CFD tools such as Fluent® and Barracuda® shall also be employed to supplement development effort of a robust solids transport and control system. These tools shall be used for quantifying mixing and distribution of multiple solid phases in the inventory. CFM test data shall be used to validate CFD analyses.

Bench-scale Tests. This subtask includes small-scale testing in a well-controlled chemical and thermal environment to evaluate various operating scenarios. A quick screening of various limestones shall also be conducted before prototype testing. The Recipient's LCL-C™ 4 Inch BSTF shall be used as required to support of the 3 MWth LCL-C™ Prototype development effort (e.g. for sulfur capture, sorbent activation, carbon conversion, etc.). Attrition and reactivity tests shall also be performed to confirm that there is no concern with excessive attrition or loss of reactivity of the solids oxygen carrier through many cycles of oxidation and reduction. These bench-scale systems shall also be used to resolve sulfur capture issues, if found to be necessary during the Technical Gap Tests in Task 3.1. Additional bench-scale apparatuses such as drop tube furnace system and the 4 inch fluid bed reactor shall also be made available for the study. The Recipient's pressurized thermo-gravimetric analyzer system with a mass spectrometer shall also be employed to assist characterization studies.

Sample Analysis and Characterization. Chemical and physical analysis of various samples generated from Prototype testing shall be carried out in this subtask. Limestone transformation, both chemical and physical, in the LCL-C™ system shall be investigated in detail. Analytical techniques for quantifying spatial distribution of calcium speciation within solid particles shall be developed. The Recipient shall also quantify various calcium species using analytic techniques. Data from prototype and bench scale testing shall be reduced and analyzed.

Subtask 3.3 – Process Refinements in Support of Prototype Operational Testing. (BP4)

Solids Transport Testing. The existing 40-foot CFM shall be utilized to support Prototype operating difficulties and for operator training on the new configuration.

Multi-phase Computational Fluid Modeling. CFD tools such as Fluent® and Barracuda® shall also be employed to supplement development effort of a robust solids transport and control system. These tools shall be used for quantifying mixing and distribution of multiple solid phases in the inventory. CFM test data shall be used to validate CFD analyses.

Bench-scale Tests. This subtask includes small-scale testing in a well-controlled chemical and thermal environment to evaluate various operating scenarios. A quick screening of various limestones shall also be conducted before prototype testing. The Recipient's LCL-C™ 4 Inch BSTF shall be used as required to support of the 3 MWth LCL-C™ Prototype development effort (e.g. for sulfur capture, sorbent activation, carbon conversion, etc.). Attrition and reactivity tests shall also be performed to confirm that there is no concern with excessive attrition or loss of reactivity of the solids oxygen carrier through many cycles of oxidation and reduction. These bench-scale systems shall also be used to resolve sulfur capture issues, if found to be necessary during the Technical Gap Tests in Task 3.1. Additional bench-scale apparatuses such as drop tube furnace system and the 4 inch fluid bed reactor shall also be made available for the study. The Recipient's pressurized thermo-gravimetric analyzer system with a mass spectrometer shall also be employed to assist characterization studies.

Sample Analysis and Characterization. Chemical and physical analysis of various samples generated from Prototype testing shall be carried out in this subtask. Limestone transformation, both chemical and physical, in the LCL-C™ system shall be investigated in detail. Analytical techniques for quantifying spatial distribution of calcium speciation within solid particles shall be developed. The Recipient shall also quantify various calcium species using analytic techniques. Data from prototype and bench scale testing shall be reduced and analyzed.

Task 4.0 - Refinement of Commercial Scale LCL-C™ Product Design and Updated Techno-Economic Analysis (BP3 and BP4)

The development of the 550 MWe LCL-C™ product design (Case 1) shall be further advanced based on lessons learned from the bench and prototype testing planned under Phase II, and the challenges and gaps identified during the design of the 550MWe net LCL-C™ plant for the Phase I. The following items shall be considered in scaling up the process and further developing the 550 MWe net LCL-C™ plants:

- **Solids separation devices:** Develop an alternate solid separator design to address higher collection efficiencies required by the larger inlet solids loading and relatively smaller size particles. The conventional cyclone design configuration used on CFBs proved inadequate to maintain satisfactory solids capture to (a) minimize solid escape, and (b) create high solids recirculation. Hence, improved cyclone configuration or alternate separation device designs shall be studied to choose a suitable design that shall result in good solid retention.
- **Backend equipment:** Develop a Reducer backend system that may include new equipment, condenser, and product gas recycle equipment to address lower quality flue gas leaving the Reducer, if necessary;
- **Reactor gas outlet sizing, number and location:** Determine number, type and location of gas and solid outlets from the reactors to ensure proper upstream process conditions;
- **Solids transfer system selection and design:** Develop an effective and

smooth transport and control system for solids exchange between the Reducer and Oxidizer through long distances and minimum headroom;

- **Fuel and limestone feeding system design:** Develop suitable fuel and limestone feeding and distribution system to the Reducer;
- **Combustion air system selection:** Develop a suitable combustion air distribution system for the air reactor to avoid high temperature agglomeration and/or sintering/pluggage on nozzles due to recarbonation caused by lower temperature fluidizing CO_2 and any CaO in the solids;
- **Boiler and LCL-C™ process integration:** Integration of USC and A-USC cycles with Chemical Looping equipment that have unique and non-conventional heating surface types, arrangements, duty splits, and allocations; and
- **Advanced controls:** Develop advanced controls system required by the more complex LCL-C™ system.

This development is driven by the feedback from prior work on LCL-C™ project that some of the conditions such as temperature, concentration of the key constituents, such as O_2, CaS, $CaSO_4$, CaO and fuel elements, need to be within certain ranges to result in acceptable product gas and solid quality. This, in turn, requires that the distribution of the key streams such as fuel, limestone, solids in and out of the reactors, and air are distributed more evenly relative to a CFB.

Once the design has been completed, the Phase I techno-economic analysis shall be revisited and updated.

3.4.4 Deliverables

The Recipient shall prepare and submit to DOE all reports in accordance with the Federal Assistance Reporting Checklist. In addition to the reports specified on the "Federal Assistance Checklist," the Recipient shall provide the following deliverables to the Project Officer identified in Block 15 of the Assistance Agreement Cover Page:

1. A Technical/Scientific Topical Report shall be provided on an annual basis no later than 30 days after each 12-month period. This annual Topical Report is to document the technical work and progress achieved during the preceding 12 months.
2. Project Management Plan (Final version due 30 days after award of Phase II

and maintained up to date by the Recipient).

In addition to the Technical/Scientific Topical Reports, a Topical Report describing specifically the Prototype testing firing North Dakota lignite fuels will be prepared and submitted to the NDIC in 90 days after the completion of the prototype testing.

3.5 LCL-C™ Oxy-Combustion Technology Commercialization

Chemical looping is one of the most promising technologies being developed for carbon capture. As discussed in the proposal, there is the need for further testing of the 3MWth prototype to address technology gaps as well as optimize the process for a variety of fuels. At the conclusion of the program, Alstom is planning on development of a large scale (~25 MWe) field validation facility. This latter step is necessary prior to scaling up to a commercial size unit in the 100 to 150 MWe range based on the experience with the development of CFBs from pilot to commercial size currently offered in the 600 MWe to 800 MWe size range.

The current test program on chemical looping development funded by the U.S. DOE and industry co-founders is investigating and demonstrating a bituminous coal. Because of the nature of the fuel, there will be additional questions about how to design for lignite. The benefit of modifying the test program to include a test campaign with lignite will be to answer these questions and demonstrate that dried and run-of-mine North Dakota lignite can be successfully processed in the LCL-C™ system. The operating conditions and performance will be optimized for dried and run-of-mine North

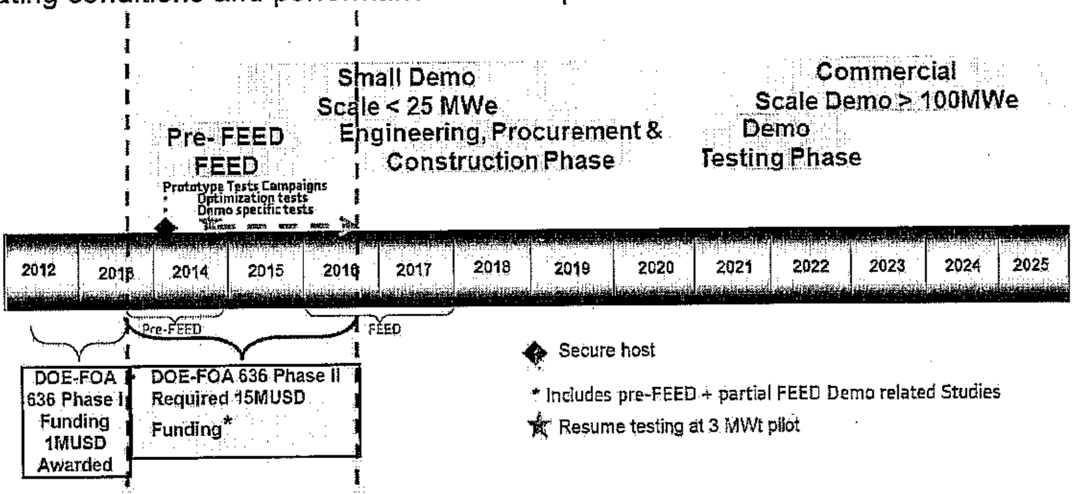

Figure 4 Overall LCL-C™ Development Timeline

Dakota lignite during the proposed testing, which will allow data for better comparison with other coals during evaluations for power plant retrofit or new plants considering this technology.

Alstom intends to commercialize this technology and has been actively pursuing development. Alstom's development path for commercialization of LCL-C™ is shown in Figure 4. At the completion of this program, Alstom will have sufficient information to proceed with a large scale field validation facility design.

4 STANDARDS OF SUCCESS

The standards of success for this project will be measured through successful pilot scale demonstration of LCL-C™ while firing dried lignite. The results of the testing will show the applicability of lignite chemical looping retrofit to existing PC and CFB boilers. The effect of sodium on the fuel/ash handling, fuel conversion, and limestone (oxygen carrier) utilization will be quantified. The benefit of pre-drying will be evaluated. Major gas species emissions measurements will show the differences in pollutants such as CO, NOx, SO_2 and HAPS form the LCL-C™ compared to air and oxy-fired systems. Ash agglomeration and deposition observations will show the applicability of lignite to the LCL-C™ system. Mercury test results will show the potential impact of LCL-C™ on in-situ mercury capture and requirement for downstream capture requirements. The performance goal of the project is to identify low-capital cost LCL-C™ designs for the range of fuels tested, maintaining minimal balance of plant impact.

5 VALUE TO NORTH DAKOTA

In North Dakota, over 18,000 jobs, $1.3 billion in business volume, and $60 million in tax revenue are generated by the lignite industry each year. North Dakota produces almost 30 million tons of lignite annually, and tens of thousands of tons of lignite are fired by North Dakota power plants daily. North Dakota's economy depends on lignite production and use.

Carbon capture and sequestration from lignite-fired boilers poses a significant technical challenge. Successful demonstration of Alstom's cost-effective LCL-C™ technology will allow continued use of lignite in an efficient and environmentally safe manner, and ultimately could help lead to the demand for greater production. Increased lignite production and use in North Dakota will result in more jobs in all lignite-related industries in the state.

Alstom is committed to achieving competitive fossil fuel power generation with near-zero emissions. Successful performance in this Phase II program would be an important stepping stone to validation of the LCL-C™ process at a field scale (10 to 25 MW_e), and eventually to scale-up to a commercial scale. In particular, successful execution of a series of LCL-C™ prototype tests is a key step to control risks and result in a successful demonstration and subsequent commercialization of LCL-C™ technology. The knowledge and experience base obtained from this program will be crucial to applying the technology to both future power plant construction and potential retrofit of the existing fleet. The compact and flexible technology also produces high purity CO_2 that allows enhanced oil recovery in North Dakota while utilizing North Dakota lignite. The program will ensure continued utilization of fossil fuels with challenging fuel properties (e.g., high sulfur or sodium) in a carbon-constrained world.

6 MANAGEMENT AND TEAM QUALIFICATIONS

The project team consists of Alstom, the US DOE, Illinois Clean Coal Institute, and subcontracted support from:

- GLAB (Dr. John Grace and Dr. Jim Lim) – Vancouver, British Columbia providing consultation on Prototype engineering, and
- Carmeuse Lime & Stone – Pittsburgh, PA providing consultation on sulfur chemistry.

Alstom is the principal contractor of the program, leading efforts on LCL-C™ process refinement, Prototype testing and data analysis, refinement of a commercial scale LCL-C™ product design and project management/reporting.

The project team will draw upon the monitoring by interested representatives from the major utilities (Great River Energy, Jamestown BPU, American Electric Power, East Kentucky Power), and industrial companies (Carmeuse, GLAB) to provide guidance and end-user perspective. The project team will also have the support of

Alstom's broad global expertise and immediate access to results on-going complementary company activity in Europe.

Alstom has an extensive background in various areas of fuel and combustion research, demonstration and commercialization. Alstom is the world's leader in the area of utility boilers. There are more than 500 Alstom-designed coal-fired utility boilers in the U.S. (40% of total coal-fired capacity). Alstom is also a leader in the development of clean coal technologies including fluidized bed combustion systems, low NO_x firing systems, furnace sorbent injection, and utilization of cleaned coals. Alstom currently has internal projects for the development and commercialization of oxy-combustion technologies for both pulverized coal (PC) and circulating fluidized bed (CFB) boilers. Alstom has considerable experience in the management and successful completion of projects with varied scope and complexity.

Alstom will make this project a high priority and will commit the appropriate resources and qualified people to the project. Key personnel, their roles and years of experience are summarized in Table 1. Resumes are provided in Appendix A. Figure 5 shows the organizational chart of the project for successful execution of the project.

Table 1 Alstom Team Organization and Key Personnel, Roles, and Experience

Project Key Personnel Project Role	Experience
Mr. Herbert E. Andrus, Jr. - Principal Investigator	Mr. Andrus led Alstom's LCL™ technology development since the late 1990's and was Principle Investigator to the U.S. DOE/NETL since federal funding began in October 2003 supporting LCL™ development. He has 38 years of experience in R&D and design of advanced power generating systems, including advanced coal fired boilers, coal gasification, fluidized bed boilers, fuel cells, high temperature sulfur removal, advanced environmental systems and other advanced power plant concepts. He is the Chemical Process Expert in Alstom's Technical Expert Community. *
Mr. Carl Edberg - Task 1 Leader –Project Management - Task 2 Leader – Prototype	Mr. Edberg has 14 years of technical and project management experience. His recent work includes auto-thermal operation of the LCL-C™ prototype facility, PC oxy-combustion development and commercialization of Alstom's MerCure™ mercury control technology.

Project Key Personnel Project Role	Experience
Test Facility	
Mr. James Kenney - Task 3 Leader – Prototype Support Activities	Mr. Kenney has 6 years of experience in laboratory research, pilot testing, gas analysis measurement techniques, and model development in the areas of combustion and chemical processes, with laboratory work on carbon gasification, metal oxide reduction, sulfur species measurement.
Mr. Glen Jukkola - Task 4 Leader – Refinement of Commercial Scale Design	Mr. Glen Jukkola leads the Systems Analysis team in Alstom's Boiler R&D organization. He will coordinate Alstom's resources in support of the proposed technical and economic studies. He has 35 years of experience in advanced power plant development including fluidized beds and advanced steam cycles. He is the Systems Analysis Expert in Alstom's Technical Expert Community.*
Mr. Iqbal Abdulally - Global R&D Program Manager - Chemical Looping Technology	Mr. Abdulally has over 35 years of technical, developmental, design, operational and managerial experience from concept to commercial operation of all types of fluidized bed steam generators and associated auxiliary and ancillary equipment. He is Alstom's chemical looping technology manager with oversight of Alstom's chemical looping activities in the U.S. and Europe. He is the Fluidized Bed Expert, Combustion & thermal process in Alstom's Technical Expert Community.*
Mr. Ray Chamberland - Contract and Alstom business point of contact	Mr. Chamberland has over 25 years of progressive and diversified experience from applied research of industrial gases and development of waste heat recovery systems to leading Alstom's Boiler research with the Boiler R&D management team. He coordinates external funding support for Alstom's Boiler R&D organization.
Dr. Shin Kang - Resource Manager and technical support	Dr. Shin Kang has over 23 years of experience in researching combustion and thermal sciences. Dr. Kang has applied his management skills and technical experience in multi-faceted product development projects. He has successfully conducted technology / product development in power generation industries based on his analytical skills, broad experience and knowledge in combustion chemistry, and mechanical design. Dr. Kang has been the principal investigator on a number of external contracts sponsored by the Department of Energy. He is the Combustion Technology Expert in Alstom's Technical Expert Community.*

*Alstom Technical Expert Community is composed of the top 5% if Engineering and Research professionals in the company who pledge to technical excellence, personal development, and knowledge sharing.

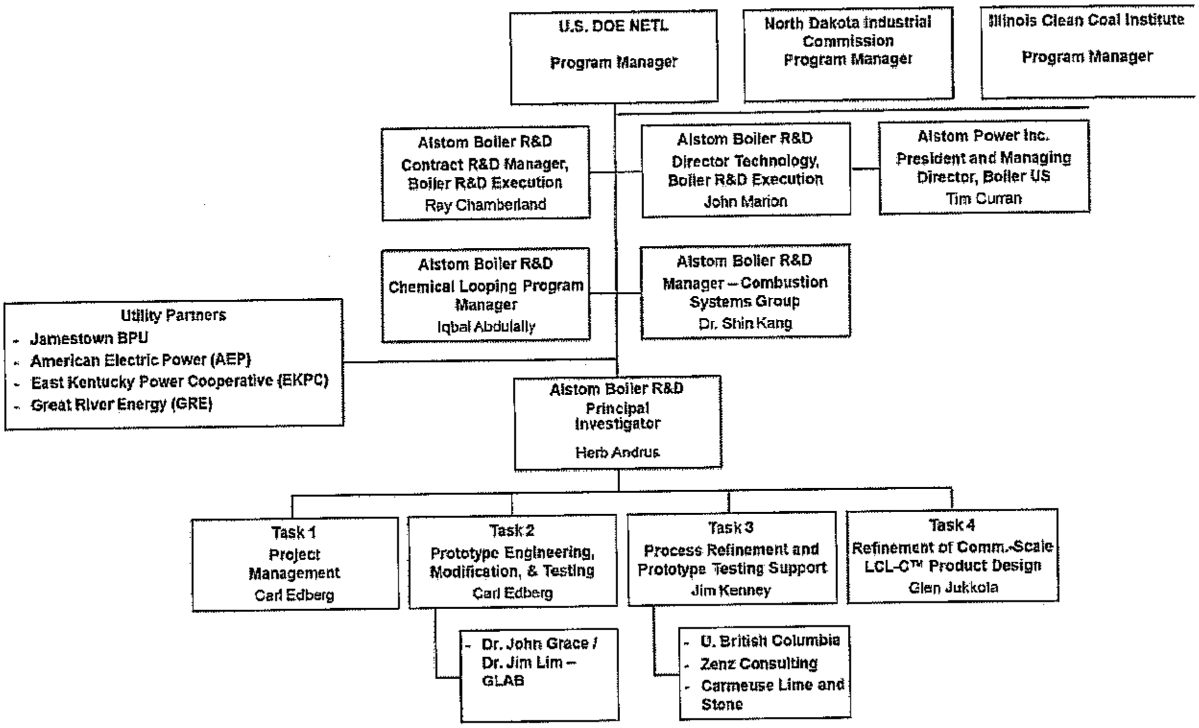

Figure 5 Project Organization Chart

Alstom Power Inc. is a global leader in power generation, environmental, and chemical process technology and has significant experience in studying and developing advanced combustion, post-combustion emissions control, and CO_2 capture systems for coal power generation. Alstom is the world's leader in the area of utility boilers with more than 801 GW of boilers installed worldwide representing about 27% of the total market [pulverized coal (PC), Circulating Fluidized Bed (CFB), and licensees]. Nearly 29% of that capacity resides in the U.S. market.

Alstom's Boiler R&D Execution group is an integral part of Alstom's worldwide corporate research network, and focuses on developing new products for the power industry. For nearly 50 years, Alstom has provided products and solutions for combustion system components and emissions control and led in the development of advanced power systems. Alstom has had considerable experience in the management and successful completion of projects, which are similar to the subject proposal from the standpoint of scope and complexity. Specific examples of recent projects related to CO_2 capture include:

- Oxy-Combustion Boiler Development for Tangential Firing, DOE/NETL Cooperative Agreement No. DE-NT0005290 / NDIC FY10-LXVIII-169 / Illinois ICCI 08-08

- Development of Computational Approaches for Simulation and Advanced Controls for Hybrid Combustion-Gasification Chemical Looping, DOE/NETL Cooperative Agreement No. DE-FC26-07NT43095

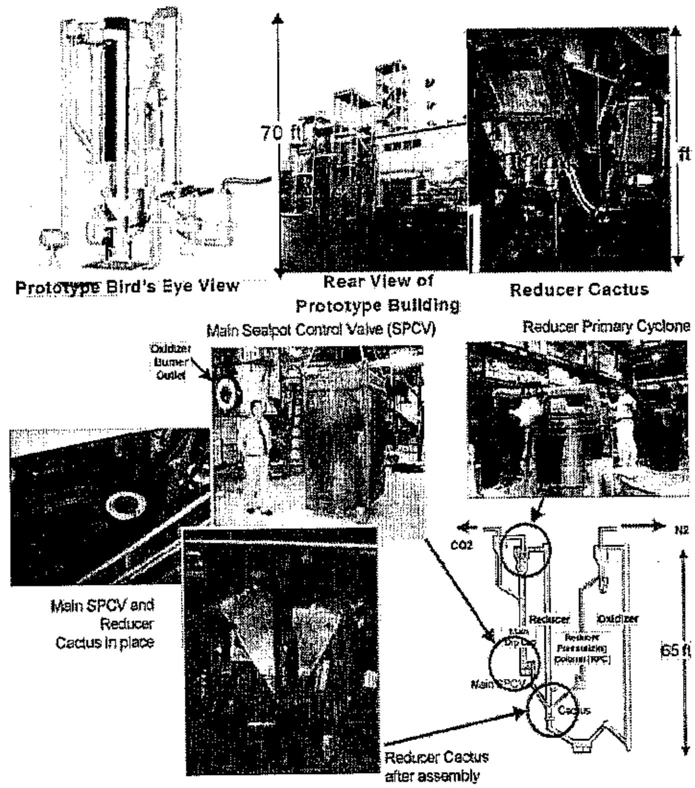

Figure 6 Alstom's 3 MWth Chemical Looping Prototype Facility

- Pilot-Scale Demonstration of a Novel, Low-Cost Oxygen Supply Process and its Integration with Oxy-Fuel Coal-Fired Boilers, DOE/NETL Cooperative Agreement No. DE-FC26-06NT42748

- Commercialization Development of Oxygen Fired CFB for Greenhouse Gas Control, DOE/NETL Cooperative Agreement No. DE-FC26-04NT42205

6.1 Alstom Test Facilities

The proposed work will be conducted at the Alstom engineering offices and lab facilities in Windsor, CT. Alstom has one of the largest and most diverse fossil power research facilities in the world, which is well suited to address the development of LCL-C™. The Alstom facilities to be used for this include the 3 MWth LCL™ prototype facility, 4-inch CFB facility, drop tube furnace system, and chemical looping cold flow models, computational fluid dynamics (CFD) resources. The LCL™ prototype facility is capable to fire 500 to 1000 lb/hr of coal and is configured as depicted in Figure 6. The prototype is currently the largest pilot- scale chemical looping test facility in the world that has demonstrated auto-thermal LCL-C™ operation of nearly 60 accumulated hours achieved.

The prototype facility consists of Reducer and Oxidizer reactors operated in transport regime. Solids circulate between the Oxidizer loop and the Reducer loop and are controlled via solids control valve, which also serve as pressure seal. The solids control valve on the Reducer side is equipped with a sorbent system in order to maintain oxygen carrier reactivity. Reducer gases exit to a combustion chamber for burnout of fuel gas species such as CO and CH_4. The exhaust gases are cleaned by a scrubber and then vented to the stack. Coal and limestone are supplied to the reducer by gravimetric feeders. Air flows for the oxidation, transport, and cooling are measured and controlled to process requirements. Gases generated in the reactors are sampled and concentrations of H_2, CO, CO_2, H_2O, and other trace gases (H_2S, NO_X, SO_2, NH_3, etc.) are determined.

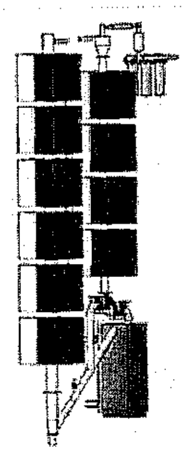

Figure 7 Schematic of bench-scale CFB

Alstom will also utilize its 4 inch CFBC facility (Figure 7). This electrically heated setup is equipped with dedicated gas analysis and data acquisition systems for on-line measurements of O_2, CO, CO_2, and NOx, SO_2, and total hydrocarbon from effluent gas streams.

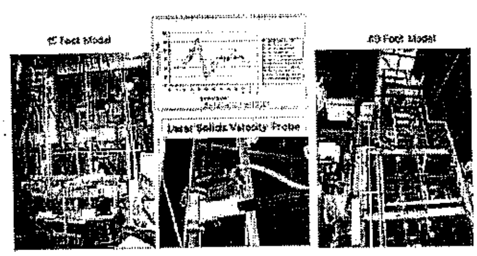

Figure 8 Chemical looping cold flow modeling facilities

Existing cold flow models for Chemical Looping include a 15-foot and a 40-foot model which simulate solids transport within the 3 MWt Chemical Looping Prototype. The cold flow models (Figure 8) are used to evaluate solids/gas transport characteristics, for Prototype problem resolution, controls trials, sealing and the associated scale-up issues, and for operator training. Alstom will conduct TGA testing at its Analytical Chemistry lab in Chattanooga, TN. This lab has a complete state-of-the-art laboratory equipped for physical and chemical testing TGA, XRD, SEM, physical characterization, trace elements, and standard ASTM tests. Additionally, Alstom will use a pressurized TGA facility with a mass spectrometer system (available by December 2013) in Windsor, CT, to conduct the testing of calcium sulfate / calcium sulfide reactions at elevated pressures.

Alstom has extensive CFD capabilities including Barracuda™ multi-phase flow simulations on an integrated high-speed network of workstations and multiprocessor servers dedicated to advanced computing applications.

7 TIMETABLE

The project schedule (Figure 9) is estimated to take 36 months to complete from the award of a DOE contract. The DOE project is organized into three 12 month budget periods (BP2, BP3, and BP4).

The solids management characterization on the existing Prototype along with CFD and cold flow modeling are planned immediately after contract award in BP2. The results of these activities will finalize proposed modification to the facility, which will be incorporated in conjunction with the relocation[1] of the prototype. The relocation will be completed in BP2 and proposed optimization testing will commence in earnest in BP3 and completed in BP4, which gives adequate time period for performing the proposed parametric test matrix on a conservative time schedule and use of available resources.

A time requirement for execution of each task is based on detailed breakdown of task activities and direct experience performing these or similar activities. The schedule for facility modifications factored in vendor quotes for long lead-time equipment and weather conditions. Realistic time was allowed for adjustments in the plan. The duration of test campaigns was estimated based on preliminary test matrices and experience on time required to stabilize conditions after parametric changes. Sufficient time was allowed between each test campaign to evaluate results of previous tests and perform maintenance and modifications to the test facility.

[1] Alstom's Prototype is scheduled to be moved from its current site at 2000 Day Hill Road to a nearby site. The move is scheduled to take place between 1 January 2014 and 30 November 2014. The Prototype relocation is considered in the proposed Phase II project schedule.

Technology transfer activities such as paper presentations and publications consistent with Alstom's development roadmap will take place as soon as results are made available. Also, meetings with program managers of the DOE, NDIC, and ICCI will take place as many times as needed throughout the development program. The final report will be submitted to the team members and program managers of the DOE/NETL, NDIC, and ICCI by the end of December 2016.

Task Name	Start
DE-FE-0009484 - Phase II	10/1/13
1.0 Project Management and Reporting	10/1/13
2.0 Prototype Engineering, Modification and Testing	10/3/13
Prototype Engineering and Modification	10/3/13
Prototype Modification Engineering	10/3/13
Prototype Modification Materials and Installation	10/3/13
Product Gas Recycle Equipment Retrofit Engineering	11/4/14
Product Gas Recycle Retrofit Materials and Modifications	2/2/15
Controls - Dynamics and Controls Development	10/3/13
Controls - Sensor Development and Testing	10/3/13
Prototype Technical Gap Tests	10/1/14
Prototype Performance Characterization and Optimization Tests	11/2/15
3.0 Process Refinement and Prototype Testing Support	10/1/13
4.0 Pre-FEED Study	10/3/13
5.0 Refinement of Commercial Scale LCL-C Plant Design	7/1/15
Advancement of 550 Mwe Design	7/1/15
Techno-Economic Analysis Update	4/1/16
6.0 FEED Study Initiation	4/1/16
MILESTONES	
Updated Project Management Plan	10/31/13
NEPA Questionnaire	10/31/13
Project Kick-off Meeting	11/30/13
Quarterly Progress / Financial Reports	12/31/13
Budget Period 1 Report / Continuation Request	6/30/14
Budget Period 1 Project Review Meeting	11/30/14
Budget Period 2 Report / Continuation Request	6/30/16
Completion of Technical Gap Prototype Testing	9/30/15
Large-Scale Field Validation Facility Pre-FEED Topical Report	9/30/15
Budget Period 2 Project Review Meeting	11/30/15
Completion of Performance Characterization and Optimization Prototype Testing	9/30/16
Large-Scale Field Validation Facility FEED Initiation Report	9/30/16
Final Project Review Meeting	9/30/16
Final Report	12/31/16

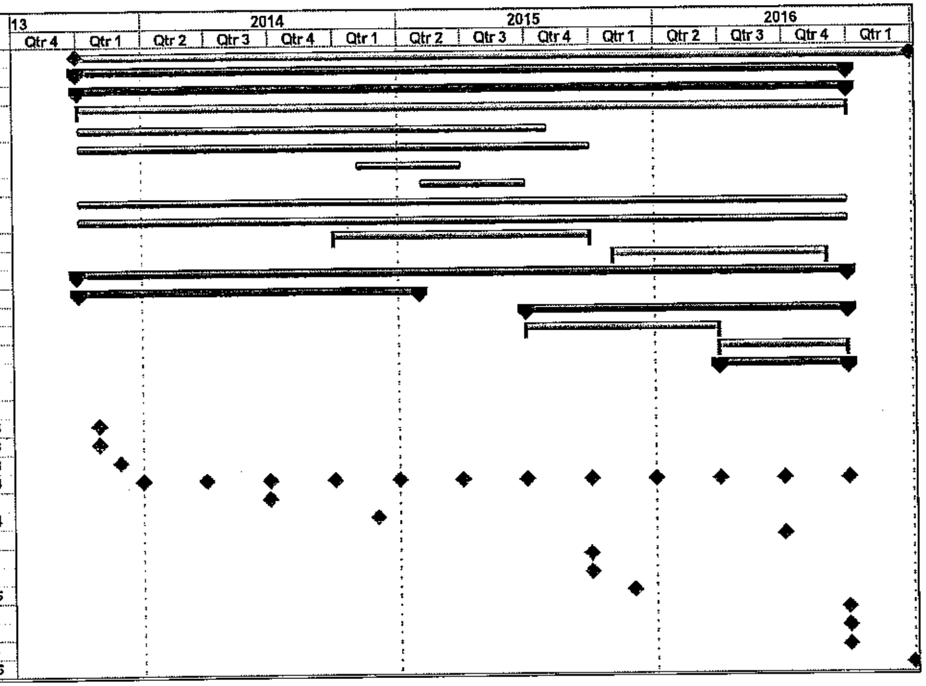

Figure 9 Preliminary Project Schedule
(to be revised based on discussion with DOE/NETL and NDIC)

8 BUDGET

The total estimated budget for the proposed program plus the DOE/NETL funded effort is $625,000. The budget estimate details are included in Appendix D, and a breakdown of cost share is provided in Section 9. Note that the budget estimate of the current DOE/NETL - Alstom program is $9,989,821. If Alstom's proposal is accepted by NDIC, then the additional proposed scope will be rolled into the DOE/NETL-sponsored three-year program and the total estimated budget will be $10,446,821.

9 MATCHING FUNDS

Funding requested from NDIC is $500,000, which is 4.8% of the total project estimated budget of $10,446,821. The project partners providing cash and in-kind funding include Alstom Power; US DOE; industry; and the Illinois Clean Coal Institute (ICCI). A detailed breakdown is provided in Table 2.

Table 2 Proposed Funding Sources for the Project

Funding Sources	Cash Cost Share	In-kind Cost Share	Total	Cost Share
NDIC	$500,000		$500,000	4.8%
Great River Energy		TBD	TBD	TBD
DOE	7,891,857		7,891,857	75.2%
Alstom Power	1,954,964		1,954,964	18.6%
ICCI	100,000		100,000	1.0%
Carmeuse Lime & Stone		43,000	43,000	0.4%
Total	$10,446,821	$43,000	$10,489,821	100.0%

10 TAX LIABILITY

As of the proposal submission date, Alstom does not have any outstanding tax liability owed to the State of North Dakota or any of its political subdivisions. Provided in Appendix C is a letter from Alstom's Sales and Use Tax Department confirming this information.

11 REFERENCES

1. Nsakala, N., Liljedahl, G., "Greenhouse Gas Emissions Control by Oxygen Firing In Circulating Fluidized Bed Boilers Phase 1 – Volume I Evaluation of Advanced Coal Combustion & Gasification Power Plants with Greenhouse Gas Emission Control," DOE/NETL DE-FC26-01NT41146, www.osti.gov (OSTI ID: 825796)

2. Andrus, Jr., H, Chiu, J, Thibeault, P, Breault, Dr. R, "ALSTOM's Hybrid Combustion-Gasification Chemical Looping Technology Development – Phase III" Pittsburgh Coal Conference, 2008

3. Andrus, H. E., Jr., et. al., "Hybrid Combustion-Gasification Chemical Looping Coal Power Technology Development – Phase I Final Report", U.S. DOE, December, 29, 2004

4. Andrus, H. E., Jr., et. al., "Hybrid Combustion-Gasification Chemical Looping Coal Power Technology Development – Phase II Final Report", U.S. DOE, June 9, 2006

5. Andrus, H. E., Jr., et. al., "Hybrid Combustion-Gasification Chemical Looping Coal Power Technology Development – Phase III Final Report", U.S. DOE, Sept, 30, 2008

6. Andrus, H. E. Jr., et al., "Alstom's Chemical Looping Combustion Prototype for CO_2 Capture From Existing Pulverized Coal-fired Power Plants Phase IVA Final Report." Alstom. Technical DOE Report for Project DE-NT0005286. 30 January 2013.

7. Andrus, H. E. Jr., et al., "Project Management Plan – Phase I." Alstom's Chemical Looping Combustion Prototype with CO_2 Capture for New and Retrofit Coal-Fired Power Plants. Technical DOE Report for Project DE-FE0009484. October 2012.

8. "Alstom Chemical Looping Combustion Technology Assessment Summary," Alstom. Update Report to DOE. 29 October 2012.

9. Liljedahl, G.L., et al., "Alstom's Oxygen-Fired CFB Technology Development Status

for CO_2 Mitigation", 31st Int'l Tech Conference on Coal Utilization & Fuel Systems, Clearwater, FL., May 2006

10. "455 MW_e CLC Boiler Feasibility Report and Recommendations for the Next Step." ENCAP Report SES6-CT-2004-502666. March 2004
11. Jukkola, G.D., "Technology Engineering Design Basis - Topical Report," Alstom. Technical DOE Report for Project. DE-FE0009484. October 2012
12. Jukkola, G.D., "Technology Engineering Design and Economic Analysis – Task 2 Topical Report." Alstom's Chemical Looping Combustion Prototype with CO_2 Capture for New and Retrofit Coal-Fired Power Plants. Alstom. Technical DOE Report for Project DE-FE0009484. 26 June 2013
13. Levasseur, A., et al., "Optimised Pollutants Removal and Gas Processing Unit Development for Oxy-Combustion." Greenhouse Gas Technologies (GHGT 11), Kytoto, Japan, Nov. 18 - 22, 2012

APPENDIX A – RESUMES

The following pages are the resumes of the key project participants identified in Section 6 of the proposal narrative.

HERBERT E. ANDRUS, Jr.
Principal Consulting Engineer, Alstom Power Inc., Boiler R&D Execution

SUMMARY OF QUALIFICATIONS
Thirty-eight years of experience at Alstom Power involving R&D and design of advanced power generating systems, including advanced coal fired boilers, coal gasification, fluidized bed boilers, fuel cells, high temperature sulfur removal, advanced environmental systems and other advanced power plant concepts. Responsible for the execution of several projects from conceptual design through mechanical design, construction and testing. Broad experience in chemical and mechanical process development, pilot plant design, testing, data analysis, process modeling, computer programming, equipment design, economic analysis, R&D program direction and project management. Directed several multi-million dollar development projects from bench scale testing to full-scale demonstration for projects including coal gasification, advanced boiler developments and environmental control systems. Several patents and numerous papers relating to power plant and environmental control technologies.

EDUCATION AND TRAINING
B. S. Chemical Engineering, University of Connecticut, 1968

RESEARCH AND PROFESSIONAL EXPERIENCE
2003 – Present Project Manager, responsible for the technical direction and project management of the US/DOE Chemical Looping Project.
2001 - 2002 Manager, CO_2 Capture Program for Boilers: Responsible for technical direction and management of Alstom Power, Inc. program to develop cost effective CO_2 capture technology for the boiler business.
1995 - 2000 R&D Project Manager, Technology and Environmental Development: Responsible for the technical direction and project management of several large development projects which resulted in the establishment of several major new commercial power plant systems.
1992 - 1995 Manager, Product Development, Gasification Product Group: Responsible for providing product line focus for technical, commercial, sales and marketing efforts for all aspects of the IGCC business and product development efforts. These activities include both the domestic and international markets, as well as licensing activities.
1988 - 1992 Coal Gasification Demonstration Project Director, Advanced Energy Systems and IGCC Development: Responsible for all aspects the Demonstration Project to demonstrate the Combustion Engineering (CE, now Alstom Power) IGCC system at CWL&P in Springfield, Illinois. Point of contact at ABB-CE for the U.S. Department of Energy (DOE), CWL&P, Illinois ENR and all other contractors/sub-contractors involved in the Demonstration Project.
1986 - 1988 Consulting Engineer, Advanced Energy Systems: Responsible for CE's coal gasification development program, Responsible for the technical evaluation of novel energy systems and the development of coal gasification, including advanced power cycle analysis, coal gasification development, data analysis and reduction, and process modeling.

1983 - 1986 Principal Engineer, Advanced Process Development: Responsible for CE's coal gasification development programs. Responsible for developing coal gasification gasifier design procedures and techniques based on performance data form CE's 120 TPD Process Development Unit and the 2 TPD pressurized coal gasification pilot plant, for use in designing large commercial gasifiers. Also responsible for pilot plant data reduction and analysis, computer program development, fuel cell system development projects, technical presentations and proposal development.
1980 - 1983 Senior R&D Engineer, Coal Gasification Development Technical Manager for the CE/Gulf States Utilities (GSU) 150 MW coal gasification demonstration project sponsored by the U.S. DOE. Responsible for the development of the demonstration plant design based on CE's air blown, atmospheric, entrained coal gasification technology. Responsible for directing and coordinating the design related activities of all project participants including various departments within CE, GSU, DOE, a major Architect and Engineer firm and various other subcontractors.
1979 - 1980 R&D Engineer, Coal Gasification Development: Responsible for coal gasification proposal preparation and estimation. Additional responsibilities include pilot plant mechanical design, data reduction and analysis; computer program development and technical presentations.
1978 - 1979 R&D Engineer, Assistant to the Director of Development Performed marketing studies, proposal and budget preparation, and technical and promotional presentations for the Coal Gasification Development Program.
1975 - 1978 R&D Engineer, Air Quality Control System Product Development Performed process engineering in support of contracts and proposals for CE's Air Quality Control System.

REPORTS AND PUBLICATIONS

- Andrus, H. E., Jr.,Chiu,J.H.,Liljedahl,G,N,Stromberg,P.T.,Thibeault, P.R., Hybrid Combustion-Gasification Chemical Looping Coal Power Technology Development – Phase 1 Final Report, U.S. DOE, December, 29, 2004.
- Andrus, H. E., Jr.,Burns,G.,Chiu,J.H.,Liljedahl,G,N,Stromberg,P.T.,Thibeault,P.R., Hybrid Combustion-Gasification Chemical Looping Coal Power Technology Development – Phase II Final Report, U.S. DOE, June, 9, 2006.
- Andrus, H. E., Jr.,Burns,G.,Chiu,J.H.,Liljedahl,G,N,Stromberg,P.T.,Thibeault,P.R., Hybrid Combustion-Gasification Chemical Looping Coal Power Technology Development – Phase III Final Report, U.S. DOE, Sept, 30, 2008.
- Andrus, H.E.,Jr.,Chiu,J.H.,Thibeault,P.R.,Dr. Breault,R.W., ALSTOM's Hybrid Combustion-Gasification Chemical Looping Technology Development – Phase III, Pittsburgh Coal Conference, 2008.
- Alstom's Chemical Looping Prototypes, Program Update; Iqbal F. Abdulally, Corinne Beal, Herbert Andrus, Alstom Power, Bernd Epple, Technische Universitat Darmstadt, Germany, Anders Lyngfelt, Chalmers Tekniska Hogskola, Goteborg, Sweden, Bruce Lani, US DOE NETL, 37th International Technical Conference on Clean Coal & Fuel Systems, Clearwater, Florida, June 3-7, 2012.

PATENTS

Process for Enhancing the Sulfur Capture Capability of an alkaline Earth Material – US Pat 6594553 4/18/00
Hot Solids Gasifier with CO2 Removal and Hydrogen - US Patent 7083658 29 May 2003
Hot Solids Gasifier with CO2 Removal and Hydrogen - US Patent 7445649 7 Jun 2006
Hot Solids Gasifier with CO2 Removal and Hydrogen - US Patent 7988752 26 Sep 2008
Reducing CO2 Emissions from the Burning of a Fossil Fuel US Patent 7896951 16 Feb 2009
A Retrofit System and Process of Combustion/Gasification of Hot Solids - US Patent 8110012 31 Jul 2009

SYNERGISTIC ACTIVITIES

Registered Professional Engineer, State of Connecticut
American Institute of Chemical Engineers

CURRENT AND PENDING SUPPORT

Alstom's Chemical Looping Combustion Technology With CO2 Capture for New and Retrofit Coal-Fired Power Plants, Phase I DOE/NETL Cooperative Agreement No. DE-FE000984 $1.0MM (US DOE), 2012 to Sept. 30, 2013, 12 person months per year.

Iqbal F. Abdulally
Technology Manager, Fluidized Bed Technology, Combustion Systems, Alstom Power Inc. – Boiler R&D Execution

SUMMARY OF QUALIFICATIONS
Thirty-five years of technical, developmental, design, operational and managerial experience from concept to commercial operation of all types of fluidized bed steam generators and associated auxiliary and ancillary equipment.

EDUCATION AND TRAINING
Loughborough University of Technology, UK, Masters of Science, Advanced Chemical Engineering

RESEARCH AND PROFESSIONAL EXPERIENCE
Alstom Power Inc., Windsor, CT
Fluidized Bed Technology Manger, Boiler R&D Execution (2010 - present)
- Technical Manager responsible for all fluidized bed related development including chemical looping.

Principle Consulting Engineer, Process and Performance Engineering, (2002 - 2010)
- Responsible for providing design and operation assistance for the development and design of all novel and scaled up fluidized bed product lines in the conceptual, proposal and contract phases. Project lead for R&D efforts related to emission reduction, improvements and standards.

Foster Wheeler NA, Clinton, NJ
Director, Performance Engineering (1997 - 2002)
- Responsible for the proposal and contract front end design of CFB and PC boilers; design tool and standards development: support field operation during commissioning and commercial closeout.

Manager, Fluidized Bed Performance Engineering (1986 - 1997)
- Responsible for the front end design of all fluidized bed steam generators during the developmental, proposal and contract design phases.

PUBLICATIONS
Papers
- Application of Foster Wheeler Fluidized Bed combustion technology in refinery waste heat recovery, I. F. Abdulally and B. Kersey, presented at the API mid-year refinery meeting in San Diego, California, May 1986.
- Refinery off-gas treatment - why the fluidized bed option?, I.F. Abdulally and B. Kersey, presented at the AIChE spring national meeting in New Orleans, Louisiana, April 1986.
- Design Considerations of Circulating Fluidized Bed Steam Generators, I.F. Abdulally, presented at the APC, 1987, Chicago, IL.

- Operating experience of a Circulating Fluidized Bed Boiler Designed by Foster Wheeler; I.F. Abdulally, et al, presented at the APC, 1989, Chicago, IL.
- Design update of the Foster Wheeler Bubbling Fluidized Bed Boiler; presented at the APC, 1989, Chicago, IL.
- Basic Considerations for the Selection and Design of a Foster Wheeler Fluidized Bed Steam Generating Unit; I.F. Abdulally, et al, presented at the Red Steam Generating Unit; presented at the FWEC International Engineering Conference May 1990, Warren, NJ.
- Update of Foster Wheeler Circulating Fluidized Bed Boiler Operating Experience; I.F. Abdulally, et al, presented at the 1990 International Joint Power Generation Conference & Exposition, October 1990, Boston, Mass. and 11th International Fluidized Bed Combustion Conference, April 1991, Montreal, Canada.
- Foster Wheeler Circulating Fluidized Bed Boiler Operating Experience Update, I. Abdulally and S. J. Goidich, Fluidized Bed Combustion Conference, 1991.
- Multiple Fuel Firing Experience in a Circulating Fluidized Bed Boiler, I. F. Abdulally, R. W. Voyles and A. Libal, American Power Conference, 1992.
- Firing Experience in a 'User-Friendly' Circulating Fluidized Bed Boiler, I. F. Abdulally and R. F. Sturzl, CIBO Fluid Bed Conference, 1992.
- Foster Wheeler Answer to Meeting the Challenge: Large Scale CFB Unit Design for the Electric Utility Market, Iqbal Abdulally and John Cox, EPRI Application of Fluidized-Bed Combustion for Power Generation Conference", 1993.
- Advanced Pressurized Circulating Fluidized Bed System: Beyond the Demonstration Stage, I. F. Abdulally and I. Alkan; Fluidized Bed Combustion Conference, 1995.
- Experience with Burning Refinery By-Products in Fluidized Bed Boilers. Scott L. Darling, Iqbal F. Abdulally, Foster Wheeler PyroPower, Presented at the 1997 Foster Wheeler International Conference May 22-23, 1997
- An update of the Operating Experiences Burning Petroleum Coke in a Utility CFB: The NISCO Cogeneration Project; Dallas W, Tharpe and I.F. Abdulally; Presented at the Fluidized Bed Combustion Conference, 1997.
- Economic, Clean and Efficient Steam and Power Generation for the Oil Sands Industry; Iqbal Abdulally and Scott Darling, Alstom Power, PennWell Oil Sands Conference, Calgary, Alberta, Canada, July 2007.
- Alstom's Chemical Looping Combustion Coal Power Technology Development Prototype; Iqbal Abdulally, Herb Andrus, Paul Thibeault and John Chiu, Alstom Power, 1st International Chemical Looping Conference Lyon, France 17-19 March 2010.
- Addressing CO2 Emission with Circulation Fluidized Bed Boilers; Iqbal Abdulally, Alstom; COAL-GEN, Pittsburgh, 11 August 2010.
- Operating Experience and Performance of East Kentucky Power Cooperative's Spurlock #4 305 MW CFB Boiler Plant; Spencer Barrett – EKPC; Iqbal. F. Abdulally, Robert Donais, Aaron Hardigan – Alstom; COAL-GEN, Pittsburgh 13 August 2010.
- Alstom's Chemical Looping Prototypes, Program Update; Iqbal F. Abdulally, Corinne Beal, Herbert Andrus, Alstom Power, Bernd Epple, Technische Universitat Darmstadt, Germany, Anders Lyngfelt, Chalmers Tekniska Hogskola, Goteborg, Sweden, Bruce Lani, US DOE NETL, 37th International Technical Conference on Clean Coal & Fuel Systems, Clearwater, Florida, June 3-7, 2012.

Patents

	US Patent No.	Description
1 (C)	4,694,758	Segmented fluidized bed combustion method
2	4,761,131	Fluidized bed flyash reinjection system
3	4,920,924	Fluidized bed steam generating system including a steam cooled cyclone separator
4	4,936,770	Sulfur sorbent feed system for a fluidized bed reactor
5	4,947,804	Fluidized bed steam generation system and method having an external heat exchanger
6	4,951,611	Fluidized bed reactor utilizing an internal solids separator
7	4,955,295	Method and system for controlling the backflow sealing efficiency and recycle rate in fluidized bed reactors
8	5,022,893	Fluidized bed steam temperature enhancement system
9 (C)	5,069,170	Fluidized bed combustion system and method having an integral recycle heat exchanger with inlet and outlet chambers
10	5,072,696	Furnace temperature control method for a fluidized bed combustion system
11	5,101,576	Uni-directional fluidization nozzle and a fluidized bed system utilizing same
12	5,133,943	Fluidized bed combustion system and method having a multi-compartment external recycle heat exchanger
13	5,140,950	Fluidized bed combustion system and method having an integral recycle heat exchanger with recycle rate control and backflow sealing
14	5,218,932	Fluidized bed reactor utilizing a baffle system and method of operating same
15	5,372,791	Fluidized bed system and a fluidization and cooling nozzle for use therein
16(C)	5,395,596	Fluidized bed reactor and method utilizing refuse derived fuel
17	5,425,331	Circulating fluidized bed reactor for low grade fuels
18 (C)	5,443,022	Fluidized bed reactor and method utilizing refuse derived fuel
19	5,462,718	System for decreasing NOx emissions from a fluidized bed reactor
20	5,463,968	Fluidized bed combustion system and method having a multicompartment variable duty recycle heat exchanger
21	5,510,085	Fluidized bed reactor including a stripper-cooler and method of operating same
22	5,553,557	Method of decreasing NOx emissions from a fluidized bed reactor

	US Patent No.	Description
23	5,567,228	System for cooling and cleaning synthesized gas using a hot gravel bed
24	Under Exam	Enhanced SNCR injection for flue gas streams containing NOx (W07/009)
25	Under Exam	Rotary ash cooler Enhancements (W09/034)
(C) Co-inventions		

SYNERGISTIC ACTIVITIES
Professional Engineering, State Board of Professional Engineers and Land Surveyors, State of New Jersey.

CURRENT AND PENDING SUPPORT
Actively involved since early 2010 in Phase IVA 3 MWth prototype efforts performed under DOE/NETL Cooperative Agreement No. DE-NT0005286, which was completed September 30, 2012.

John Chiu
Senior Consulting Engineer, Alstom Power Inc., Critical Technology Execution

SUMMARY OF QUALIFICATIONS:
Mr. Chiu has forty years diversified experiences in the design and development of energy systems and related equipment. He served as a technical representative for the company and a project coordinator between research, engineering, purchasing and clients. He is specialized in solids/gas fluidization and transport hydrodynamic process, boiler water/steam circulation, thermodynamics, heat and mass transfer. Past experiences included: designing/analysis of conventional and advanced steam generator and balance of power plant equipment; test analysis and performance code development; power plant retrofit study; boiler performance optimization; power plant cost assessment; and technical/commercial negotiation.

EDUCATION:
Post Graduate study in Mechanical Engineering, Rensselaer Polytechnical Institute
Master of Science in Mechanical Engineering, Kansas State University, 1972
Bachelor of Science in Mechanical Engineering, National Cheng Kung University, 1968

PROFESSIONAL EXPERIENCES:
Alstom Power Inc., 2000 to Present

Senior Consulting Engineer, Combustion Technology
Mr. Chiu was responsible for various design and development in energy system related process, component, and performance. Special experiences include:

- developed Alstom's chemical looping process
- developed CFB process model and key CFB fundamental researches
- served as the Technical representative for the AIMS (Analogies in Matters of Science) Technical Advisory Board
- developed the CFB process model and CFB fundamental research

ABB, Inc., 1990 to 2000

Senior Consulting Engineer, Advanced System Development

- served as technical consultant on GEF China Industrial Efficiency for World Bank
- invented and developed the steam reactivation process for CFB spent ash sulfur reduction
- was a key designer of the 10MWt multi-test Facility pilot plant
- completed the cyclone optimization and cost reduction program for a CFB steam generator

Combustion Engineering, Inc. 1973 to 1990

Principal Engineer, Advanced System Development

- Mr. Chiu was the principal investigator for the design and development of a 435MW supercritical sliding pressure advanced pulverized coal boiler. Experiences included: design and select component of steam generator and balance of plant; optimize the water circulation systems for a CFB unit; design/retrofit of a limestone injecting boiler; design a conceptual heat and seed recovery system for the DOE MHD test facility; develop a drum steam/water separator; design CFB for an air turbine cogenerating system; design/retrofit oil/gas unit for coal water mixture fuel; managing CE project for the Assessment of CFB technology for utility application for the Steam Rogers/EPRI.

Senior Engineer, Design Applications Development

Developed, tested, and analyzed the field/laboratory experiments in thermal, heat and mass transfer code development such as the rifled tube DNB and furnace thermal performance. Provided technical assistance and training to company personnel and licensees. Assisted design and development of Coolwater for Syngas cooling. Performed the design and cost estimation for proposal writing.

PERSONAL BACKGROUND

Consultant on GEF China Industrial Efficiency for World Bank, 1997
Trainee of CFB Tech-Transfer by Lurgi GmbH, W. Germany, 1988

PUBLICATIONS (selected)

- "Alstom's Hybrid Combustion Gasification Chemical Looping Technology Development – Phase II", 23rd Pittsburgh International Coal Conference, October 2006.
- "Alstom's Hybrid Combustion-Gasification Chemical Looping Technology Development – Phase III", 25th Pittsburgh International Coal Conference, Outstanding paper award of the conference, October 2008.
- "Alstom's Chemical Looping Combustion Coal Power Technology Development Prototype", 26th Pittsburgh International Coal Conference, September 2009.
- "Alstom's Calcium Oxide Chemical Looping Combustion Prototype Program", 28th International Pittsburgh Coal Conference, September 2011.
- "Spent Sorbent Reactivation Using Steam", 13th International Conference on FBC, 1995.
- Energy Economic Data Base (EEDB) Program Phase IX (Ninth; Update (1987) - EEDB Phase IX Technical Reference Book, Prepared for Oak Ridge National Laboratory, subcontract No. ORNL/Sub-87-30X-86004V/2, R. Allen, J.H. Chiu et al, 1988.
- "Comparison of a Year 2000 Atmospheric Circulating Fluidized Bed and Conventional Coal-Fired Power Plant Technical Features and Costs", The Tenth

International Conference on Fluidized Bed Combustion, R.E. Allen, J.H. Chiu, and C.R. Bozzuto, et al, San Francisco, California, May, 1989.

CARL D. EDBERG

Consulting R&D Engineer, Alstom Power Inc., Combustion Research and Technology

SUMMARY OF QUALIFICATIONS

Thirteen years of technical and project management experience; contributing to new product development from within both the aftermarket and new equipment organizations. Broad range of equipment development experience for advanced coal fired boilers and advanced environmental control systems. Experienced in mechanical / chemical process development, bench / pilot / prototype-scale test facility design, testing and data analysis.

EDUCATION AND TRAINING

University of Massachusetts, Amherst, BS, Mechanical Engineering (1996)
University of Massachusetts, Amherst, MS, Mechanical Engineering (2001)

RESEARCH AND PROFESSIONAL EXPERIENCE

Alstom Power Inc., Windsor, CT

Consulting R&D Engineer, Combustion Research and Technology, (2006 – Present)

- Directing execution of large-scale internal and third-party testing campaigns intended to identify prospective technologies and validate design performance. Targeted technologies include those addressing CCS and Utility/Boiler MACT.

Senior Mechanical Engineer, Electronic Systems Application Engineering, (2003 - 2006)

- Diverse set of responsibilities involving all phases of Coordinated Product Lifecycle Management, (PLM) for the Limelight™ product family of burners, ignitors and controls.

Senior R&D Engineer, Mechanical Systems Engineering, Power Plant Labs, (1999 - 2003)

- Developed and tested new products and processes across a broad range of applications for internal business units. Offered robust problem solving capability to address technical field issues.

PUBLICATIONS

- *"Alstom's Calcium Oxide Chemical Looping Prototype, Program Update,"* H. Andrus, J. Chiu, P. Thibeault, C. Edberg. Presented at the 2011 Pittsburgh Coal Conference, September 12 – 15, 2011.

- *"Assessment of Oxy-Combustion Impacts on Boiler Design and Performance During 15MWth Pilot-scale Testing,"* A. Levasseur, C. Edberg, J. Kenney, P. Chapman, D. Turek, S. Kang. Presented at the Ninth Annual Carbon Capture & Sequestration Conference, May 10 - 13, 2010.

CURRENT AND PENDING SUPPORT

Alstom's Chemical Looping Combustion Technology with CO2 Capture for New and Retrofit Coal-Fired Power Plants
Alstom/DOE Collaborative Agreement, DE-FE0009484
Total project funding - $1,249,989
Expectation is to work 3 person-months per year for DOE FY13.

Alstom's Chemical Looping Combustion Prototype for CO2 Capture from Existing Pulverized Coal Fired Power Plants
Alstom/DOE Collaborative Agreement, DE-NT0005286
Total project funding - $9,244,530. There is no expected work on this project for DOE FY14.

Glen D. Jukkola
Technology Manager, Alstom Power Inc. – Boiler R&D Execution

SUMMARY OF QUALIFICATIONS
Thirty-five years of technical and managerial experience in the development of conventional pulverized coal fired boilers, fluidized bed boilers, and advanced steam generation systems. A broad range of experience in fluidized bed process analysis and modeling, economic analysis, equipment development, and plant start-up support.

EDUCATION AND TRAINING
University of Connecticut, BS, Chemical Engineering (1976)
Cornell University, Masters of Engineering, Chemical Engineering (1977)
Rensselaer Polytechnic Institute, Masters in Business Administration (1987)

RESEARCH AND PROFESSIONAL EXPERIENCE
Technology Manager, ALSTOM Power, Windsor, CT (2010 – present)
- Responsible for managing technical and economic analyses of new and emerging technologies for the power plant industry, including advanced steam generator concepts and CO_2 capture control technologies.

Manager, Systems Analysis, ALSTOM Power, Windsor, CT (2006 – 2010)
- Responsible for managing technical and economic analyses of new and emerging technologies for the power plant industry, including advanced steam generator concepts and CO_2 capture control technologies.

Senior Technical Fellow, ABB Combustion Engineering, Windsor, CT (1998 - present)
- Technical Manager for AACFB – conceptual design, development, commercialization of Advanced CFB concept

Director, Combustion Technology, ABB Combustion Engineering, Windsor, CT (1996 - 1998)
- Project Manager for AACFB – conceptual design, development, commercialization of Advanced CFB concept. Overall responsibility for design, construction, and operational of new Multi-Use Combustion Test Facility

Director, Process Engineering and Design ABB Combustion Engineering, Windsor, CT (1991 - Dec 96)
- Responsible for the technical and economic analysis of new and emerging technologies for the power plant industry and for developing and demonstrating promising technologies, and for the development of improvements to existing steam generation technologies.

Manager, Generating Systems Development, Combustion Engineering, Windsor, CT (1988 - 1991)
- Responsible for the process, component, and performance design development for a wide range of steam generating equipment provided by Fossil Systems Business,

including circulating and bubbling atmospheric fluidized beds and conventional fossil fired units.

Consulting/Principal Engineer, FBC Development, Combustion Engineering (1981-1988)
Project Engineer, Fuels Research, Combustion Engineering (1977-1981)

- Responsible for the technical development and evaluation of new processes related to bubbling and circulating fluidized beds, including performance analysis of the TVA 20MW Pilot Plant, technical support for the TVA 160MW Demonstration Plant design, the Scott Paper CFB test program, the Great Lakes BFB Demonstration Plant.

PUBLICATIONS

18 publications including conference technical papers, magazine articles, and textbook chapters

- "CMB Proof of Concept Final Report – Phase II", G. Jukkola, DOE, Oct 2010
- "Expanding the Clean Coal Portfolio: Oxyfiring to Enhance CO2 Capture," by G. Jukkola, Greg Liljedahl, Nsakala Nsakala, Dave Turek, Frank Kluger, presented at the 23rd International Pittsburgh Coal Conference, September 2006.
- "An ALSTOM Vision of Future CFB Technology Based Power Plant Concepts," by G. Jukkola, Greg Liljedahl, Nsakala Nsakala, Herb Andrus, Jean-Xavier, Morin, presented at the 18th International Conference on Fluidized Bed Combustion, Toronto, Ontario, 2005.
- "CMB Proof of Concept Phase I Project," by G. Jukkola, Power Magazine, September 2003.
- "CMB Proof of Concept Final Report", G. Jukkola, DOE, April 2003.
- "Performance Results with Alstom's Circulating Moving Bed Combustor," by G. Jukkola, A. Levasseur, B. Teigen, P. Thibeault, D. Turek, S. Jain, presented at the 17th International Conference on Fluidized Bed Combustion, Jacksonville, Florida, 2003.
- "Operating Experience with ABB Power Plant Laboratories Multi-Use Combustion Test Facility", by G. Jukkola, A. Levasseur, D. Mylchreest, D. Turek, presented at the 15th International FBC Conference, Savannah, Georgia, May, 1999.
- "Fluidized Bed Combustion", Combustion, 4th Edition, J. Singer, editor, Combustion Engineering, Windsor, CT, 1991.
- "Fuel Preparation Systems for TVA's 160MW Demonstration Plant", by G. Jukkola, R. Kunkel, and G. Dunn, presented at the Joint Power Generation Conference, Philadelphia, PA, August, 1988.

PATENTS

Awarded 8 patents related to advanced boiler and process design, with another 11 patents pending

G.D. Jukkola, J.E. Ferguson, J.F. Durant, R.S. Rogers, "*Sorbent Conditioning and Direct Feed Apparatus for a Steam Generator and a Method for Retrofitting a Steam Generator with Same,*" U.S. Patent 6,615,750, Issued 9/9/2003.

G.D. Jukkola, M.S. McCartney, P.R. Thibeault, "*Recuperative and Conductive Heat Transfer System,*" U.S. Patent 6,554,061, Issued 4/29/2003.

G.D. Jukkola, R. Rogers, N. Phyfe, "*Separating Carbon From Ash,*" U.S. Patent 5,976,224, Issued 11/2/99.

G.D. Jukkola, J.H. Chiu, M.J. Hargrove, M.A. Douglas, S.A. Morrison, S.Y. Wong, "*Internal Circulation Fluidized Bed (ICFB) Combustion System and Method of Operation Thereof,*" U.S. Patent 5,401,130, Issued 12/23/93.

G. D. Jukkola, H. Andrus, M. S. McCartney, "*Reducing Carbon Dioxide Emissions From the Burning of a Fossil Fuel*", (filed 8/20/09), US Patent 7.798,951, March 1, 2011, W01/013-1.

SYNERGISTIC ACTIVITIES

Coal Utilization Research Council (CURC)

- Act as Alstom's representative to CURC, which is an industry coal advocacy group. Act as chairman of the Advanced Combustion and Existing Plant Technical Subcommittee, and participate in several working groups for developing CURC technology positions and updated CURC/EPRI technology roadmaps.

EPRI CoalFleet for Tomorrow

- Act as Alstom's representative to EPRI's CoalFleet program, which is an industry-lead initiative to accelerate the deployment and commercialization of clean, efficient power systems.

Adjunct Professor, School of Engineering and Science, Rennselaer Polytechnic Institute (1988-1998)

- Responsible for preparation and presentation of a graduate-level course in Engineering Economics. Topics covered included time value of money, discounted cash flow methods, depreciation and income taxes, decision making uncertainty, inflation, and capital budgeting.

CURRENT AND PENDING SUPPORT

All technical work is currently funded internally by Alstom.

Dr. Shin G. Kang
Director, Combustion Research, Alstom Power Inc. - Power Plant Laboratories

SUMMARY OF QUALIFICATIONS
Dr. Shin Kang has over 23 years of experience in researching combustion and thermal sciences. Dr. Kang has applied his management skills and technical experience in multi-faceted product development projects. He has successfully conducted technology / product development in power generation industries based on his analytical skills, broad experience and knowledge in combustion chemistry, and mechanical design. Dr. Kang has been the principal investigator on a number of external contracts sponsored by the Department of Energy.

EDUCATION
Masters in Business Administration, Rensselaer Polytechnic Institute, Hartford, CT, 2005
Chemical Engineering, PhD (minor in Materials Science and Engineering), Massachusetts Institute of Technology, Cambridge MA, 1991
Chemical Engineering, MS, University of Cincinnati, Cincinnati OH, 1986
Chemical Engineering, BS Cum Laude, Seoul National University, Seoul Korea, 1984

PROFESSIONAL EXPERIENCE
Jan 2008 – Present Alstom Power, Windsor, CT
- Director, Combustion Research: Manages a variety of product development activities on PC and CFB boilers as well as post-combustion equipment that include analytical, computational fluid dynamics and experimental work.

Feb 1998 – Jan 2008 Alstom Power, Windsor, CT
- Technical Fellow, Product Development and Technology; Senior Consulting Engineer, Combustion Technology: Led projects for development of new combustion products for new business areas including petrochemical industries. Worked on a high-visibility, high- impact project in a cross-disciplinary focus team on development of new power generation processes. Activities ranged from conceptual design, bench-scale and pilot-scale feasibility tests, economic and market analysis, identification of potential customers, securing funding, to full-scale demonstration.

Oct 1995 – Jan 1998 John Zink Company, a Koch Industries Company, Tulsa, OK
- Manager, Combustion Product Development Group; Senior Principal Engineer: Supervised a number of projects for development and improvement of combustion products and technology for petrochemical industries. Supervised warranty projects for troubleshooting products for customers. Initiated product standardization efforts. Provided business groups with technical/consulting support through technical review, and risk evaluation on commercial projects. Developed training courses and programs for engineers. Evaluated technologies of candidate M&A companies and various product concepts from external sources.

Dec 1991 – Sep 1995 Physical Sciences Inc., Andover, MA
- Principal Research Scientist; Principal Scientist: Secured research funding from various federal agencies (DOE, DOD, NASA, NSF, etc.); performed various projects on combustion, emission control, and high-temperature materials processing as Principal Investigator; worked on consulting and contract R&D projects for utility industry.

PUBLICATIONS

Authored more than 25 technical papers

PATENTS

Patents include:
WO 2009/158465, "A furnace system with internal flue gas recirculation"
U.S. Patent 6,848,374, "Control of Mercury Emissions from Solid Fuel Combustion"
WO 2004/108254, "Method and Apparatus for removing mercury from flue gas combustion"
U.S. Patent 6,749,681, "Method of Producing Cement Clinker and Electricity"
WO 2001/073343, "Method of producing steam and an alternate product in a power plant"
U.S. Patent 6,193,940 B1, "Firing Systems for the Improved Performance of Ethylene Cracking Furnaces"

SYNERGISTIC ACTIVITIES

Member, American Institute of Chemical Engineers;
Editorial Board member, International Flame Research Foundation

<u>**JAMES R. KENNEY**</u>
R&D Engineer, Alstom Power Inc., Boiler R&D Execution

SUMMARY OF QUALIFICATIONS

Four years of experience at Alstom Power involving research and development activities in advanced power plant development systems. Mr. Kenney has experience in laboratory research, pilot testing, gas analysis measurement techniques, and model development in the areas of combustion and chemical processes, with laboratory work on carbon gasification, metal oxide reduction, sulfur species measurement. Mr. Kenney has been deeply involved in pilot-scale testing of oxy-combustion technology through the Alstom – DOE/NETL program to develop oxy-combustion boiler technology for tangential firing (DOE/NETL Cooperative Agreement No. DE-NT0005290).

EDUCATION AND TRAINING

Carnegie Mellon University, BS, Chemical Engineering, 2008
Carnegie Mellon University, Masters of Engineering, Chemical Engineering, 2009

RESEARCH AND PROFESSIONAL EXPERIENCE

<u>2009 – Present</u> R&D Engineer, Alstom Power Boiler R&D Execution. Performed a range of engineering and experimental tasks, including test design, equipment construction, pilot plant operation, data analysis, and documentation. Work involves combustion process with an emphasis on advanced power plant development. Test program leader for a novel waste incineration system and a 100% biomass burner development. Other major programs involved in include oxy combustion boiler development for tangential firing, and chemical looping combustion.

PUBLICATIONS

- *"Assessment of Oxy-Combustion Impacts on Boiler Design and Performance During 15MWth Pilot-scale Testing,"* A. Levasseur, C. Edberg, J. Kenney, P. Chapman, D. Turek, S. Kang. Presented at the Ninth Annual Carbon Capture & Sequestration Conference, May 10 - 13, 2010.

- *"SO3 Emissions From a Tangentially-Fired Pilot Scale Boiler Operating Under Oxy-Combustion Conditions,"* J. R. Kenney, M. M. Clark, A. A. Levasseur, and S. G. Kang. Presented at the American Institute of Chemical Engineers 2010 Annual Meeting, November 7 – 12, 2010.

- *"Oxy-Combustion Boiler Design and Performance Impacts Determined During 15 MWth Testing,"* A. Levasseur, D. Turek, J. Kenney, P. Chapman, S. Kang. Presented at the 36th International Technical Conference on Clean Coal and Fuel Systems, June 5 - 9, 2011.

- *"Oxy-Fired Tangential Boiler Development and Large-scale (15 MWth) Validation,"* A. Levasseur, D. Turek, J. Kenney, P. Chapman, S. Kang. Presented at the 2nd International Oxy-Combustion Conference, September 14, 2011.

- *"Untersuchung von Lausitzer Braunkohle an einer 15 MWth Oxy Pilotanlage mit Tangentialfeuerung,"* F. Kluger, P. Monckert, T. Wild, J. Kenney, A. Levasseur, D. Turek. Presented at the 43rd annual Kraftwerkstechnische Kolloquium, October, 2011.

- *"15 MWth and 30 MWth Oxy-Combustion Pilot Testing of Lignite from Vattenfall's Lusatia Open Cast Mine,"* F. Kluger, T. Wild, P. Moenckert, A. Levasseur, D. Turek, J. Kenney. Presented at the 37th International Technical Conference on Clean Coal and Fuel Systems, June 3 - 7, 2012.

- *"Updated Overview of a Manufacturer's Efforts to Commercialize Oxy-Combustion for Steam Power Plants,"* A. Levasseur, J. Kenney, T. Pourchot, B. Prodhomme, O. Stallman. Presented at the 38th International Technical Conference on Clean Coal and Fuel Systems, June 2 - 7, 2013.

CURRENT AND PENDING SUPPORT

Oxy combustion boiler development for Industrial-Scale boiler applications
Alstom/DOE collaborative agreement, DE-NT0005290
Total project funding - $21,400,000.
Expectation is to work 4 person-months per year to be devoted to that project for DOE FY13.

Alstom's Chemical Looping Combustion Prototype for CO2 Capture from Existing Pulverized Coal Fired Power Plants
Alstom/DOE collaborative agreement, DE-NT0005286
Total project funding - $7,400,000.
There is no expected work on this project for DOE FY13.

APPENDIX B – LETTER OF SUPPORT

A Letter of support from Great River Energy is provided on the following page.

GREAT RIVER ENERGY®

Bismarck Office • 1611 East Century Avenue • Suite 200 • Bismarck, North Dakota 58503 • 701-250-2165 • Fax 701-255-5405

September 13, 2013

Ms. Karlene Fine, Executive Director
North Dakota Industrial Commission
Lignite Research, Development and Marketing Program
State Capitol, 14th Floor, 600 E Boulevard Ave. Dept. 405
Bismarck, ND 58505-0840

Dear Ms. Karlene Fine,

Letter of Support to Continue Development of Alstom's Limestone Chemical Looping LCL-C™ Process Alstom's Proposal to the North Dakota Industrial Commission and Phase II Proposal to the DOE/NETL under Cooperative Agreement No. DE-FE0009484

Great River Energy (GRE) is pleased to submit this letter of support and interest to continue development of Limestone Chemical Looping LCL-C™ process, a proposal to the North Dakota Industrial Commission (NDIC) and to the Phase II Proposal to the DOE/NETL under Cooperative Agreement No. DE-FE0009484 (Funding Opportunity No. DE-FOA-0000636, Phase II).

This proposed work thus far strongly suggests that it has the potential to meet the US DOE's objective to remove over 90% of the total carbon in the coal as CO_2 for use or sequestration at a 35% or less increase in the cost of electricity from existing or new coal-fired power plants. It therefore meets the criteria for near-zero emission and employs oxy-combustion technology which utilizes limestone as an oxygen carrier.

Great River Energy strongly supports Alstom's subject proposal to the DOE/NETL, which seeks to develop a transformational coal power technology with CO_2 capture and separation. Great River Energy plans to closely monitor the LCL-C™ program described in the enclosed proposal

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River Energy plans to closely monitor the LCL-C™ program described in the enclosed proposal by Alstom. Great River Energy is the wholesale electric supplier for 28 member cooperatives in Minnesota and Wisconsin. Great River Energy is concerned about the environment and is

aware of the greenhouse gas emissions raised by the scientific community. With approximately 50% of the electric generation coming from coal-fired power plants, GRE recognizes the need to develop and demonstrate CO_2 mitigation options for the existing coal fired power generation fleet. GRE endorses the subject proposed program as an important step to develop and demonstrate lower cost CO_2 mitigation options such as chemical looping. This program has the potential to help allow the continued use of coal fuel, our nation's largest domestic energy resource.

We look forward to NDIC's review of the Alstom proposal and partnering on this interesting and needed project.

Sincerely,

GREAT RIVER ENERGY

Charles Bullinger, P.E.
Senior Principle Engineer
Great River Energy
cbullinger@GREnergy.com
(701)442-7001

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APPENDIX C – STATEMENT OF ALSTOM TAX LIABILITY IN NORTH DAKOTA

The following is a letter from Alstom's Sales and Use Tax Department providing a statement of Alstom's tax liability to the State of North Dakota or any of its political subdivisions.

ALSTOM

US
Tax Services

September 5, 2013

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
600 East Boulevard Avenue
State Capitol, 10th Floor
Bismarck, ND 58505-0310

Re: Alstom Power Inc. Proposal to North Dakota Industrial Commission – Statement on Alstom Tax Liabilities in North Dakota

Dear Ms. Fine:

In reference to the Alstom Power Inc. proposal to the North Dakota Industrial Commission titled "Alstom's Chemical Looping Combustion Technology with CO_2 Capture for New and Retrofit Coal-fired Power Plants," this letter confirms that as of this date Alstom Power Inc. (Alstom) has no outstanding tax liability owed to the State of North Dakota or any of its political subdivisions.

Should there be any questions, please contact Ray Chamberland, Manager, Contract R&D, Boiler R&D at (860) 285-3825.

Sincerely,

Ronald R. Papke
Sr. Tax Manager
Phone: (860) 285-5237
Fax: (860) 285-9587
email: ronald.r.papke@power.alstom.com

cc: Shin Kang – Alstom Power Inc.
Ray P. Chamberland – Alstom Power Inc.

ALSTOM Power Inc
200 Great Pond Drive
Windsor, CT 06095
Tel: (860) 285-5237
Fax: (860) 285-9587

APPENDIX D – DETAILED BUDGET INFORMATION

NOTICE OF RESTRICTION ON DISCLOSURE AND USE OF DATA

The data contained in pages [66 - 71] of this Appendix D – Detailed Budget Information and Appendix E – Alstom Chemical Looping Technology Development Roadmap have been submitted in confidence and contain trade secrets or proprietary information, and such data shall be used by North Dakota Industrial Commission only for the purpose of evaluating the suitability of an award to the applicant. This restriction does not limit North Dakota Industrial Commission's right to use or disclose data that does not constitute trade secret or proprietary information of the applicant.

12 PROJECT BUDGET

This proposal to NDIC is to add a test campaign that will study ND lignite coals to a DOE-funded Advanced Oxy-combustion project at Alstom's Power Plant Laboratories. The DOE-funded scope includes bench tests and Prototype test campaigns firing US bituminous coal, in the LCL™ chemical looping process. As mentioned previously, bench test and an additional Prototype test campaign of dried and run-of-mine North Dakota lignite require $625,000. The budget estimate of the additional Prototype test campaign is summarized in Table 3.

Table 3 Project Budget Estimate

Category	Tests with ND Lignite
Personnel	$371,364
Travel	0
Equipment/Supplies	174,331
Contractual	0
Direct - Subtotal	545,695
Indirect	79,305
Total	$625,000

The DOE/NETL has provisionally awarded Phase II funding of $7,891,857. At this time, no additional funding is available from DOE for added scope. Therefore, the project cost for the added lignite test program has to be provided by the project team. Other project partners providing cash and in-kind funding include Alstom Power, ICCI and Carmeuse. In this proposal, the project team requests $500,000 from NDIC as cash cost share. If less funding is available than requested, then the additional suggested tests with ND lignite would not be conducted.

A detailed breakdown of cost share is provided in Table 4. The only funding sources for this proposed test program are NDIC, Alstom, Carmeuse (in-kind), and the DOE. A Letter of Support from Great River Energy is included in Appendix B.

Table 4 Funding Sources for the Project

Funding Sources	Cash Cost Share	In-kind Cost Share	Total	Cost Share
NDIC	$500,000		$500,000	4.8
DOE	7,891,857		7,891,857	75.2
Alstom Power	1,954,964		1,954,964	18.6
ICCI	100,000		100,000	1.0
Carmeuse		43,000	43,000	0.4
Total	$10,446,821	$43,000	$10,489,821	100.0

12.2 Additional Cost Detail

Table 5 Additional Cost Detail

Description	Cost
4" Test Apparatus Modification	$50,000
Equipment Repair;	2,009
Gas Analyzer Rentals;	3,214
Gas Analyzer Calibration Gas;	1,607
N2 Trailer Rental - 1 Month ($150/Day);	3,616
CO2 Trailer Rental - 1 Month ($2.4K/month);	1,928
Ash ($7K/40yd-Warrier Run);	5,625
Coal fuel;	5,625
Limestone sorbent;	1,607
Misc. Test Consumables;	2,411
Natural Gas Usage ($2K/Day-1);	9,642
Electricity Usage ($1.2K/Day);	5,785
CO2 Usage ($.6K/Day);	2,893
N2 Usage ($1.2K/Day);	5,785
Coal Crushing Service;	6,428
Ash Disposal	11,249
Coal Disposal;	5,625
Scrubber Water Disposal ($2.5K/load);	8,035
Northeast Industrial - Facility Cleaning	11,249
Sample Testing by Alstom Chatt, Carmeuse	30,000
Planned Materials and Supplies Total	$174,331