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Large Pilot Testing of Linde-BASF Advanced Post-Combustion Carbon Dioxide Capture Technology at a Coal-Fired Power Plant

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Abstract

This first-of-its-kind, large-scale pilot is vital to the carbon capture knowledge base and experience. It will also serve as a reference for future commercial projects and provide critical design and operations information needed to scale-up the technology for commercial implementation, while minimizing costs and risks. The pilot is a 10 MWe slipstream taken from Dallman #4 at City Water, Light, and Power (CWLP) in Springfield, Illinois. The post-combustion capture technology being demonstrated is the Linde/BASF advanced capture system, which has been previously demonstrated at the National Carbon Capture Center at a 1.5 MWe level. The successful construction and operation of this plant will provide a means to demonstrate an economically attractive and transformational capture technology that can be used to retrofit existing plants and be deployed at new plants. The regional economic benefit and the ability to repurpose some exiting workforce at CWLP will also demonstrate how carbon capture can aid regional economies when it is deployed. If the technology performs as planned, the capture plant will remain in place and be utilized for future testing of capture and utilization technologies.

Keywords: Carbon Capture; CO_2 Capture; Large Pilot; Solvent-Based Capture; Post Combustion; Amines

1. Introduction

This project is a part of a US Department of Energy (DOE) initiative to design, build, and operate large pilot testing facilities for transformative carbon capture technologies. Large pilot testing is defined as systems that are 10 MWe and have feed streams that are actual flue gases from power plants. The objective of the project is to not only evaluate the capture technology, but also provide a methodology for future retrofits of existing power plants with capture technologies. The team is led by the Prairie Research Institute (PRI) within the University of Illinois at Urbana-Champaign (UIUC). Linde and affiliates provide the inside battery limits (ISBL) design and fabrication. BASF

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provides the proprietary solvent. Affiliated Engineers, Inc (AEI) provides the design for the outside battery limits (OSBL). ACS provides the procurement and construction management for the OSBL. The host site is a coal-fired power plant at City Water, Light, and Power (CWLP). Phase I of the project was a preliminary analysis, while Phase II progressed to a full front-end engineering and design (FEED) study. Phase III will be the construction and operation of the facility.

2. Project Organization

The project organization is shown in Fig 1. PRI/UIUC is the lead organization for the project. PRI/UIUC is the awardee due to their experience with DOE, experience in commercialization, and knowledge of the framework and pathway for to deploy large scale capture facilities within the State of Illinois. PRI/UIUC is strong in large project management skills, is equipped for DOE reporting at the financial and technical level and has very long-term relationships with CWLP. CWLP is also one of the sources for carbon dioxide (CO_2) outlined in a parallel CO_2 storage project also funded by the DOE – CarbonSafe. PRI/UIUC is leading this storage project as well. Coordination between the capture and storage projects is facilitated by the fact that PRI/UIUC is leading both efforts.

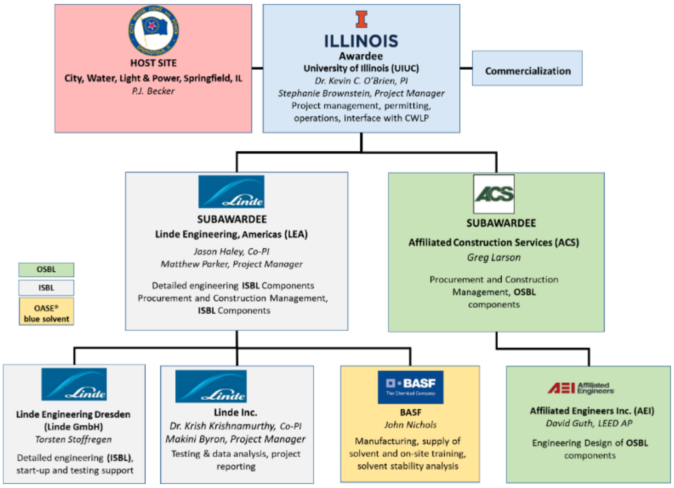

Fig. 1. Project organization.

The organizational structure is simple and easy to manage with a minimum amount of contracting required and a limited number of highly experienced partners who have a history of working together, e.g. all partners have worked together through Phases I and II. PRI/UIUC will serve as the prime contractor for this proposal and will provide overall project management, be the primary contact with the host site, ensure proper permitting, and lead efforts for technology commercialization. PRI/UIUC will manage and coordinate the work of Linde Engineering (ISBL procurement and construction). Under Linde Engineering are various Linde organizations and BASF (the solvent supplier). PRI/UIUC will also manage ACS (OSBL procurement and construction). All project partners are familiar with the challenges of retrofitting coal-fired power plants with the Linde/BASF capture technology.

3. Description of Power Plant

The CWLP power plant supplies both electricity as well as water to Springfield, Illinois – state capitol of Illinois. Springfield is located approximately 200 miles southwest of Chicago. CWLP has four coal-fired steam turbinegenerators with a total nameplate capacity of 578 MW. This project focuses on capturing a 10 MW slipstream from the Dallman #4 unit at CWLP. A schematic for the unit and the location of the capture unit is shown in Fig. 2. This unit is a nominal 200 MW pulverized coal (PC)-fired unit that became operational in 2009 [1]. It employs a Foster Wheeler front and rear wall-fired PC boiler equipped with low oxides of nitrogen (NO_x) burners; a selective catalytic reduction (SCR) unit for NO_x removal; a hydrated lime injection (HLI) system for sulfur trioxide (SO_3) removal; a fabric baghouse to capture particles; a flue gas desulfurization (FGD) system to mitigate sulfur dioxide (SO_2) emissions; and a wet electrostatic precipitator (WESP) to remove liquid droplets such as sulfuric acid mist. The slipstream will be removed just before the flue gas enters the stack.

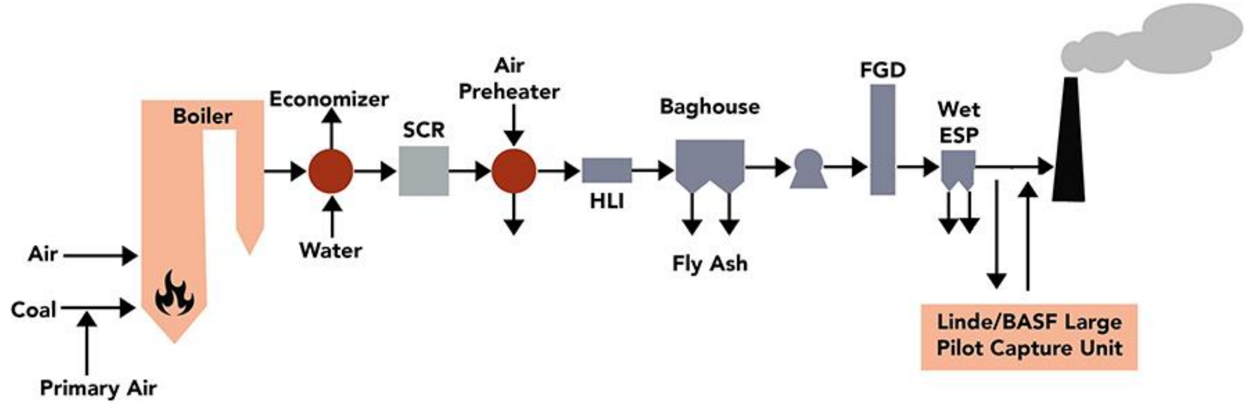

Fig. 2. Schematic of CWLP and proposed location of capture unit.

Design steam conditions at the superheat outlet are 1,055 °F and 2,950 psig. The reheat outlet conditions are 1,053 °F and 875 psig. Dallman #4 unit is designed to burn 100% Illinois high-sulfur bituminous coal with a heat content of ~10,500 Btu/lb.

The 10 MWe large-scale capture pilot represents only 5% of the generation capability of Dallman #4 and less than 2% of the capacity of the plant. The infrastructure of the host site allows ready slipstream testing. The facility runs exclusively Illinois coal and runs 24/7 (except for scheduled maintenance periods). As described above, CWLP has traditional pulverized coal (PC) boilers and traditional pollution abatement equipment (i.e., baghouse, SCR, FGD, WESP).

3.1. Off Take of Flue Gas and Location of Capture Plant

One of the engineering issues that needed to be addressed was the OSBL connection. As mentioned previously, the slipstream will be pulled from the duct that is between the WESP and the stack. The supply and treated gas return location for the flue gas will be in a location with limited space. The location of where the breach in the ducting will occur is shown in Fig. 3a (red arrow) and 3b (white circle). The connection will be made at a location that is over 150 feet in elevation from the ground. OSBL connections to the capture plant must also navigate around an existing conveyor system as shown in Fig. 3c. The ground location where the capture facility will be constructed is indicated by the red arrow in Fig. 3c. These factors have been accounted for in the design and costing.

The CO_2 capture pilot plant will be located on the west side of the CWLP facility. Fig. 4 shows the Dallman #4 unit at CWLP and the rectangle outlines the proposed location of the capture plant. The pilot plant's footprint will fall within a footprint of approximately 425' x 120', which is available at the host site. Proposed utility hook-ups and the ducting to the capture plant are indicated by the purple lines. Yellow markings indicate supports for the duct work from Dallman #4 to the capture plant.

(a) (b) (c)

Fig. 3. Engineering considerations when designing and constructing OSBL. (a - red arrow & b - white circle) location where the breach in the ducting will occur; (c - red arrow) ground construction location of the capture facility.

Fig. 4. Dallman #4 unit at CWLP with proposed capture plant location (hatched rectangle); purple lines - utilities; yellow boxes - duct work supports.

4. Capture Technology

4.1. Description of Capture Process

BASF's early solvent development efforts resulted in the formulation of next generation line of solvents – OASE® blue. The impact of the optimized properties of OASE® blue solvent on reduced capital cost of equipment originates from various factors: (1) efficient CO_2 capture from low pressure sources; (2) demonstrated longer stability than other available compounds; and (3) a lower solvent circulation rate. BASF's solvent design is complemented by Linde's

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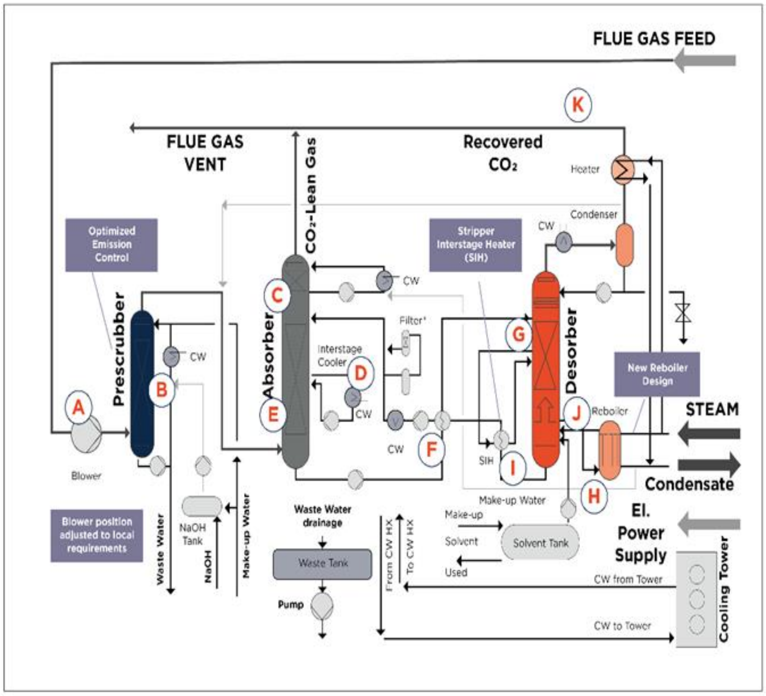
process improvements. This combination of improved solvent and improved process has been shown to reduce CO_2 capture costs at coal-fired power plants. The Linde/BASF process and the process improvements that have been achieved during the development of the technology have been previously discussed [2]. These advancements in equipment and process design options, coupled with the OASE® blue solvent, minimize the energy requirements for CO_2 removal and compression relative to the DOE/NETL Case B12B reference conditions [3].

The Linde/BASF post-combustion carbon capture (PCC) plant is designed to recover at least 90% of the CO_2 contained in the flue gas and purify the CO_2 to pipeline quality (> 99.9 vol% CO_2 (dry basis), < 50 vol. ppm O_2). For a commercial installation, where the CO_2 is transported via pipeline, the CO_2 will be dehydrated to a dew point <-40 °F and compressed to 2215 psia.

The process flow diagram (PFD) in Fig. 5 details the Linde/BASF capture process. Details of specific components are indicated and described. Of interest are the direct contact cooler (DCC) with SO_2 polishing scrubber (**B**); absorber with water wash and high capacity structured packing (**C, E**); and the advanced stripper interstage heater (SIH) (**I**).



A. Flue gas blower, provides sufficient pressure to overcome the pressure drop across the pre-scrubber and absorber. The blower location will be adjusted to host side-specific equipment in the most cost-effective manner.

B. Integrated pre-scrubber and direct contact cooler (DCC) to reduce SOx content below 5ppm and simultaneously cool the flue gas stream to -35-40°C.

C. Innovative and patented water wash section at the top of the column to reduce amine losses, even in the presence of aerosols.

D. A gravity-driven inter-stage cooler for the absorber that eliminates the pump and the controls.

E. High capacity structured packing reduces the absorber diameter, thereby enabling a larger single train plant construction.

F. Solvent-based heat exchanger designed to operate over a wide range of temperature approaches which provides the opportunity to optimize the performance and capital cost trade-off

G. Regenerator designed for operation at pressures up to 3.4 bars, significantly reduces CO_2 compression energy and eliminates the bulky first stage of the CO_2 compressor, resulting in capital cost savings

H. Innovative plate and frame design of the reboiler minimizes thermal degradation of solvent and provides for a lower solvent inventory and faster dynamics to respond to load changes.

I. Stripper Inter-Stage Heater (SIH) enhances energy efficient CO_2 stripping from the solvent by recovering heat from the lean solvent to provide intermediate reboil, thereby reducing energy consumption of solvent regeneration.

J. Variations of the stripper-reboiler flashing configuration, which are being evaluated for an ultimate reduction of solvent regeneration energy.

K. Optional CO_2 recycle stream, provided to evaluate the effect of plant loading and variable CO_2 concentration in the flue gas on overall energy consumption, and to limit the effects of power plant loading on flue gas CO_2 mol% fluctuations.

Fig. 5. Process flow diagram (PFD) for Linde/BASF process.

The DCC (**B**) has two functions: (1) to cool down the incoming flue gas stream to a temperature suitable for efficient CO_2 absorption and (2) to provide an aqueous solution of sodium hydroxide (NaOH) to reduce the SO_2 concentration in the gas entering the absorber to as low a level as possible to minimize solvent degradation due to the formation of SO_2-amine complexes.

For this host site, the flue gas stream to the DCC (**B**) is water-saturated flue gas removed just upstream from the stack. It is post flue gas desulfurization (FGD) unit and post wet electrostatic precipitator (WESP) unit, typically at atmospheric pressure and a temperature of 120 to 140 °F (approximately 50-60 °C). An aqueous solution of NaOH is

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injected into the water-NaOH circulation loop, and then sprayed at the top of the DCC unit. More than 90% of the incoming SO_2 is scrubbed from the vapor-phase via counter-current contact of the cold aqueous NaOH solution with warm flue gas. The liquid from the bottom of the DCC bed is fed to a circulating pump; the excess water, condensed from the flue gas, along with any dissolved sodium bicarbonate ($NaHCO_3$), sodium bisulfite ($NaHSO_3$), and sodium sulfite (Na_2SO_3), is withdrawn from the loop and sent to an acid neutralization and water treatment facility, while the majority of the aqueous NaOH solution in the recirculation loop is cooled with water.

An efficient reduction of the solvent losses and related reduction in emissions is achieved by utilizing the water wash section (located in **C**) positioned above the absorber bed. The flue gas with depleted CO_2 content that leaves the absorber bed still carries a small amount of solvent. Cold water, sprayed at the top of the wash unit, effectively scrubs the solvent from the flue gas, which is enhanced by significantly reduced equilibrium composition of the solvent components in the vapor-phase, caused by the reduced outlet temperature. An external plate and frame cooler in the water recirculation loop transfers the required cooling duty from the cooling water supplied by the central cooling water system.

The absorber combines an interstage cooler (**D**) with high-capacity packing (**E**). The solvent solution flows down through the absorber bed and efficiently absorbs CO_2 from the flue gas, which flows from the bottom to the top of the column and further to the water wash unit (located in **C**). Because the exothermic chemisorption reaction of CO_2 with amine-based solvents increases the temperature of the flue gas (and consequently reduces the equilibrium content of CO_2 in the liquid phase), it is of utmost importance to maintain a low, relatively constant temperature throughout the entire absorber. In addition to cooling the CO_2-lean amine solvent solution within an external cooler before it is injected to the top of the absorber, a significant solvent temperature increase within the column can be efficiently suppressed by utilizing an interstage cooler. Linde’s patent-protected, gravity-driven interstage cooler design eliminates the need for an external interstage cooler pump and consequently leads to a simplified design, as well as reduced capital costs.

The Linde/BASF PCC technology also utilizes the most advanced structured packing for the absorber to promote efficient hydraulic contact of gas and liquid phases, which along with increased CO_2 reaction rates with BASF’s OASE® blue solvent, facilitates a fast approach to equilibrium CO_2 concentration in the liquid phase. Consequently, the capacity of the absorber (**C**) is significantly increased, this being one of the most critical parameters for a large-scale CO_2 absorption plant. In addition, the advanced structured packing reduces the pressure drop across the column, which in turn leads to reduced flue gas blower requirements. The structured packing selection has been based on optimization of different structured packing offering higher capacities, while trading off on the mass-transfer efficiency.

The Linde/BASF advanced PCC technology also heats the solvent within the stripper by employing an interstage heater (**I**). The stripper interstage heater can use heat available from the lean solution, instead of steam from the reboiler, to warm up the liquid stream from the intermediate location on the stripper. The vapor generated from this heat exchange is returned to the same intermediate location. This heat integration reduces the requirement for net steam input to the reboiler, which ultimately leads to reduced operating costs.

One of the other major advantages of the Linde/BASF technology is the ability to manage aerosols and reduce amine losses. ***The absorber and water wash units (C), with its patented dry bed configuration, reduce amine carryover originating from aerosol particles. This provides a major advantage over other alternative solvent capture systems. This system was previously deployed during 1.5 MWe testing at the National Carbon Capture Center.***

5. Detailed Design and Operation Plan

The translation of PFD shown in Fig. 5 to an actual 10 MW PCC facility layout is shown in Fig. 6. The layout of the plant has been adjusted in order to fit the available area indicated in Fig. 4. Flue gas supply and return and utility supply/return piping, indicated below, are both 40 inches in diameter. The pilot plant is designed for installation on a 300 ft x 120 ft concrete slab. The PCC facility contains: (1) three free-standing columns (absorber, stripper, and DCC);

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(2) two process modules containing the other vessels; (3) heat exchangers, circulating pumps and other equipment; (4) a tank farm for solvent storage and contaminated water storage; (5) a pipe rack for the routing of utilities; and (6) an analytical container for pilot plant process control, sampling, and analytical measurements.

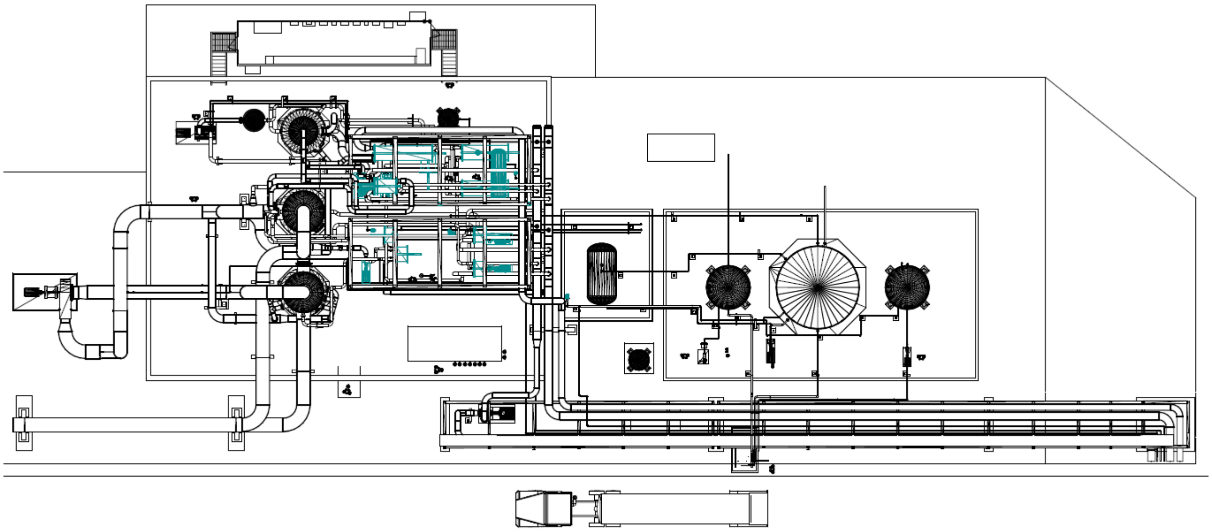

Fig. 6. Layout for 10 MW PCC facility.

One of the key aspects of the detailed engineering approach was the completion of a three-dimensional (3D) model of the pilot plant layout scaled to the dimensions of the host site. This allowed for an estimate of process piping specifications and routing for an accurate piping cost estimate based on material take-offs (MTOs) for piping. Screenshots from this 3D model are shown in Fig. 7. These renderings examine the PCC facility looking down from the power plant (Fig. 7a) and look back towards the power plant (Fig. 7b). The rendering shown in Fig. 7 is a 30% 3D model review of the PCC facility. This model review was critical to identifying any further design changes required and finalizing the design basis and specification for the layout of major equipment and piping. The model was also used to validate constructability and operability of the pilot plant.

Equipment, module, and construction vendor bid packages were completed and firm price quotations received from multiple vendors for each category. An initial estimate for the cost of preparing the site with concrete foundation for supporting the weight of the columns and equipment was also completed. To support this analysis, geotechnical and soil boring studies were conducted based on the locations identified for placement of the columns and process modules.

An operations plan specifications document was developed by Linde. The operations plan calls for four (4) dedicated operators working on 24/7 shifts to attend to routine inspection, maintenance activities, and any batch sampling required. Specialized staff, including an instrumentation and electrical engineering technician, safety specialists and maintenance support would be sourced from existing Linde operations. The pilot plant was designed for automatic operation from a central control room (CCR). However, continuous supervision by a panel operator is specified for all times. Panel operator intervention will typically only be required for situations like load changes or optimization of performance at variable feed gas conditions. For start-up and troubleshooting additional field operator intervention will be required.

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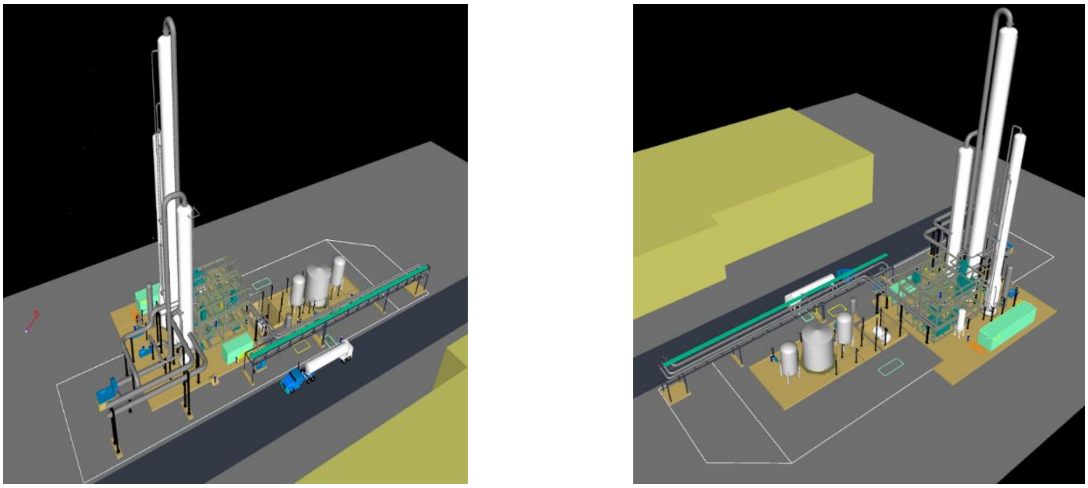

(a) (b)

Fig. 7. 3D renderings of PCC facility: (a) looking down from power plant, (b) looking back towards power plant.

6. Techno-Economic Analysis

Based on results from small pilot studies and the techno-economic analysis (TEA), the technology will achieve high CO_2 capture (~90%) and generate high purity (>99.9%) captured CO_2 in a cost-effective manner. TEA results indicated that when the proposed advanced Linde/BASF technology is integrated with a 550-MWe net supercritical PC power plant there will be an increase in power plant efficiency of approximately 3% (relative), a nominal 11.4% reduction in cost of electricity (COE), and 18% reduction in capital costs compared to the DOE/National Energy Technology Laboratory (NETL) base case (Case B12B reference) [3]. This reduction results in the cost of captured CO_2 approaching the DOE/NETL target of \$30/tCO_2. These advances are the result of BASF’s novel amine-based process combined with Linde’s process and engineering innovations, which address challenges in using solvent-based technologies for carbon capture at large coal power plants.

Projected capital and operating costs, based on the TEA, are detailed in Table 1 and Table 2. The three options for the Linde/BASF technology shown are: (1) a previously presented Linde/BASF PCC plant incorporating BASF’s OASE® blue aqueous amine-based solvent (LB1) [4]; (2) ***the Linde/BASF design to be used for this large pilot: OASE® blue solvent with an advanced stripper interstage heater (SIH) design to optimize heat recovery in the PCC process***; and (3) advanced Linde/BASF PCC plant using the OASE® blue solvent, SIH configuration, and waste heat recovery (WHR) from power plant. Waste heat recovery would occur from the flue gas at the outlet of the selective catalytic reduction (SCR) and outlet of the induced draft (ID) fans, prior to entering the flue gas desulfurization (FGD) unit (details of the SCR, ID, and FGD described and illustrated in Fig. 5).

Table 1 indicates an increase in Higher Heat Value (HHV) plant efficiency (%) for the Linde/BASF design relative to the base case. For the case to be used in the Phase II and Phase III work (SIH), this results in approximately 3% increase in the Linde/BASF SIH case over the baseline case. The impact of this increase in plant efficiency can be seen in Table 2. The capital costs of the Linde/BASF SIH case are nearly 19% less than those for the baseline case. The driver behind this reduction in capital cost with increased efficiency is the reduction in the volume of coal required to generate 550 MW net power relative to the base case. This reduction results in less CO_2 produced in the flue gas and a smaller plant (hence lower capital costs) relative to the base case. It is important to note that the capital cost for the SIH design includes the cost of the SIH.

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Table 1. Process performance and cost summary for DOE/NETL case references compared to Linde/BASF PCC technologies.

Parameter	DOE/NETL Case B12A	DOE/NETL Case B12B	Linde/BASF LB1	Linde/BASF SIH	Linde/BASG WHR
Description	No capture	90% capture with Cansolv process	90% capture OASE© Blue	90% capture OASE© Blue and SIH	90% capture OASE© Blue and WHR
Net Power Output (MW)	550	550	550	550	550
Gross power output (MW)	580	642	630	629	626
Coal flow rate (tonne/hr)	179.2	224.8	221.9	218.5	210
Net HHV plant efficiency	40.70%	32.50%	32.88%	33.40%	34.73%
Total overnight cost ($2011) ($/MM)	$1,379	$2,384	$1,970	$1,950	$1,921
Cost of CO2 captured with T&S ($/MT)	n/a	$69.01	$54.58	$53.72	$52.31
Cost of CO2 capture without T&S ($/MT)	n/a	$58.00	$43.58	$42.71	$41.31
COE ($/MWh) with T&S	$82.30	$142.80	$127.97	$126.50	$123.63

Table 2. Capital costs (thousands USD) for Linde/BASF cases relative to DOE-NETL baseline B12B.

Capital Cost Element	Case B12B	Linde/BASF LB1	Linde/BASF SIH	Linde/BASF WHR
Coal and sorbent handling	$52,286	$51,840	$51,305	$49,962
Coal and sorbent prep and feed	$24,983	$24,770	$24,514	$23,873
Feedwater and misc. BOP systems	$112,150	$111,194	$110,046	$107,166
PC boiler	$400,793	$397,378	$393,275	$382,980
Flue gas clean-up	$197,475	$195,792	$193,771	$188,698
CO_2 removal	$533,757	$239,798	$237,322	$231,109
CO_2 compression and drying	$98,381	$59,428	$58,814	$57,275
Heat and power integration	$0	$0	$0	$18,141
Combustion turbine/accessories	$0	$0	$0	$0
HRSG, ducting, and stack	$45,027	$44,643	$44,182	$43,026
Steam turbine generator	$178,176	$176,658	$174,834	$170,257
Cooling water system	$62,254	$61,724	$61,086	$59,487
Ash/spent sorbent handling system	$19,028	$18,866	$$18,671	$18,182
Accessory electric plant	$93,584	$92,787	$91,828	$89,425
Instrumentation and control	$31,654	$31,384	$31,060	$30,247
Improvements to site	$18,063	$17,909	$17,714	$17,260
Buildings and structure	$71,531	$70,922	$70,189	$68,352
Total plant cost (TPC)	$1,939,142	$1,595,094	$1,578,622	$1,55,440
Reproduction costs	$59,957	$52,991	$52,559	$51,840
Inventory capital	$41,125	$39,033	$38,506	$37,284
Initial cost catalyst and chemicals	$0	$0	$0	$0
Land	$900	$740	$733	$722
Other owner’s costs	$290,871	$239,264	$236,793	$233,316
Financing cost	$52,357	$43,068	$42,623	$41,997

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Total overnight costs (TOC)	$2,384,351	$1,970,190	$1,949,836	$1,920,598

Another advantage of the Linde/BASF technology relates to energy consumption. This process has a reduced energy consumption for solvent regeneration compared to DOE's benchmark. This reduction is indicated in the PCC specific reboiler duty row in Table 1. The technology to be tested in Phases II and III (Linde/BASF SIH) has a specific energy target of 2.30 GJ/tonne CO_2. This value is 7% lower than the current DOE benchmark (2.48 GJ/tonne CO_2).

The COE for each of the cases outlined Table 1 and Table 2 has been summarized in Fig. 8. The Linde/BASF SIH provides over 11% reduction in COE relative to the base case. It is important to note that the incremental reduction in cost of CO_2 captured ($/tonne CO_2) with increasingly higher performing CO_2 capture systems becomes smaller and smaller due to lower overall CO_2 production from higher efficiency power plants. Hence, the COE metric is more useful for analysis of performance for the CO_2 capture technology options presented in this proposal and for comparison with DOE/NETL Case B12B.

It is reasonable to expect that as the Linde/BASF technology is deployed at the n^{th} power plant, there will be further reductions in costs, thereby approaching the DOE/NETL goal of at least 30% lower COE by 2030 for new coal-fired power plants integrating transformational CO_2 capture technology compared to a supercritical PC power plant with standard CO_2 capture processes, or approximately $30/tCO2 captured [5].

There is another major advantage of the Linde/BASF cases over the base case that has NOT been captured in the current TEA. In addition to reducing the COE, the Linde-BASF SIH design can handle higher aerosol presence in the flue gas of coal-fired power plants than other PCC options.

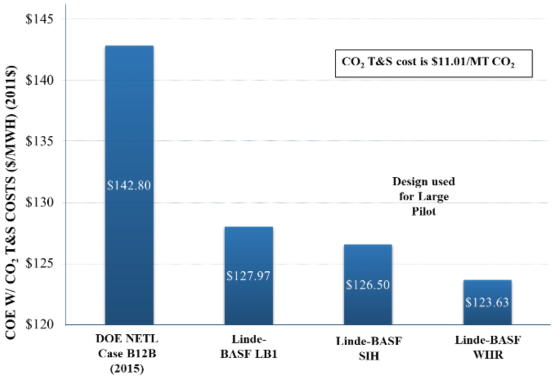

Fig. 8. Itemized capital costs for a 550 MW supercritical pulverized coal power plant integrated with Linde / BASF PCC technology as compared to DOE-NETL case B12B.

7. Regulatory and Permitting

The National Environmental Policy Act (NEPA) process begins when a federal agency develops a proposal to take a major federal action. These actions are defined at 40 CFR 1508.1. The environmental review under NEPA can involve three different levels of analysis: (1) categorical exclusion determination (CATEX); (2) environmental assessment (EA); and (3) environmental impact statement (EIS) [6]. It was determined that this required the preparation of an EA by a NEPA contractor. After the EA was conducted, a finding of no significant impact (FONSI) was determined.

During Phase II the project team has actively involved regulatory, utility, industry, and compliance stakeholders during the process of permit development and application preparation. Key areas of interest for permitting include construction, wastewater, storm water, and air emissions. Permitting paperwork will be prepared and ready for submission during the early stages of Phase III.

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The management of wastewater was especially important. The types of wastewater streams and their management are as follows:

1. Amine contaminated water (typically 1 to 2% by volume of amine) will be minimized by recycling this water in the process, where possible. A reclamation unit will also be installed to recover amines for reuse, reducing solvent makeup. Remaining amine-contaminated water will be collected and shipped offsite.
2. Non-contaminated storm water can be sent to the host site storm water drain.
3. Process condensate from the direct contact cooler (DCC) contains a mixture of bicarbonates, bisulfites, and sulfites at 0.2% or less by weight. The DCC condensate will be treated to remove/reduce these salts before discharging to the local sanitary district (Sangamon County Waste Reclamation District (SCRWD).

8. Regional Economic Benefits of Project

The benefit of this project is not only to demonstrate the capture technology, but that it will create a facility where future capture and utilization (i.e., non-enhanced oil recovery [EOR] technologies) large pilot testing can be performed. Some of the follow-on projects that have been discussed including utilizing the captured CO_2 for the growth of algae and/or incorporating the CO_2 into the production of chemicals and polymers. For example, a related DOE/NETL project has looked at using CO_2 for the growth of algae at the CWLP site. The algae could then be harvested for animal feed, biochar, or biofuel production [7]. CWLP is also one of the CO_2 sources in a storage program funded by DOE/NETL – CarbonSAFE [8]. Underground storage sites for the CO_2 are reasonably close to the power plant.

A regional economic study is also being conducted using the IMPLAN (https://implan.com/) model. This model pulls in economic data and up-to-date multipliers to generate economic impact of projects and activities. The model is used to quantitatively determine the ability of this project to generate direct, indirect, and induced economic and fiscal impact in the local community, region, and state. This impact includes influences such as new industries for CO_2 utilization, increased tourism to visit and analyse the capture facility, and other regional clusters, which will be spawned as a result of creating a regional supply chain for capture CO_2. Preliminary results project that the construction phase of the project (2022 and 2023) is estimated to generate over $42 million in total direct, indirect, and induced regional spending (economic activity/impact). Construction of the project is estimated to support/create 81 direct, indirect, and induced jobs in 2022; and 116 direct, indirect, and induced jobs in 2023. The operations phase of the project (2024 through 2027) is estimated to generate over $29.6 million in total direct, indirect, and induced regional spending (economic activity/impact). Operations from the project are estimated to support/create approximately 19 direct, indirect, and induced jobs each year. It important to note that these results are for a relatively small project, i.e., 10 MW.

To determine what could happen for a full-scale project, it is important to examine some broader studies that illustrate the positive impact that carbon capture, utilization, and storage (CCUS) can have on the regional economy of the State of Illinois. Studies have projected that for coal power generation alone within Illinois, a growth of between 2,130 to 3,200 jobs related to capital investments in CCUS and between 1,360 to 2,040 on-going jobs related to CCUS [9].

9. Summary

The build/operate (i.e., Phase III) portion of this project is a culmination of an extensive analysis of the feasibility of a 10 MW large capture pilot at an existing coal-fired power plant (i.e., CWLP in Springfield, Illinois). Implementation of this project results in the largest capture pilot in the world and provides a methodology for retrofitting other power plants with the Linde/BASF capture technology. It also provides a site for future testing at the 10 MW scale of capture and utilization (i.e., non-EOR) technologies and a means to mature technologies developed

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under other DOE awards. It is also included as a CO_2 source in an existing CO_2 storage projects. Both ISBL and OSBL detailed engineering demonstrates that the capture facility can be located close to the unit of interest. Analysis of 3D models demonstrated the constructability of the capture facility. The permitting requirements are well understood and the NEPA has been successfully completed. Strategies for the management of waste streams have been developed and incorporated into the design. Based on results from small pilot studies and a TEA study, the technology will achieve high capture (~90%) and generate high purity (>99.9%) captured CO_2 in a cost-effective manner. TEA results also indicated that when the proposed advanced Linde/BASF technology is integrated with a 550 MWe net supercritical PC power plant there will be an increase in power plant efficiency of approximately 3% (relative), a nominal 13% reduction in COE, and 18% reduction in capital costs compared to the DOE/NETL Case B12B. This reduction results in the cost of captured CO_2 approaching the DOE/NETL target of \$30/tCO_2. The regional economic benefits of this project indicates how carbon capture projects can be used to stimulate regional economies.

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