CCS Business Case Report

Project No.: PRO 004

Recipient: American Electric Power Service Corporation

Project: Mountaineer Commercial Scale Carbon Capture and Storage (CCS) Project

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1. Synopsis

The purpose of this report is to examine the issues surrounding installation of carbon capture technology on AEP's generating fleet based on lessons learned from American Electric Power's (AEP) project at Mountaineer coal fired generating station. This report discusses the following issues associated with justification and use of this technology:

- AEP is an investor owned utility with an obligation to provide electric service. The company is subject to governmental regulation which has implications on AEP's ability to finance a commercial scale CCS project.
- Financial modeling completed by AEP and discussion of results. The report also uses output of modeling and looks at financial risks and the need for financial incentives to fund first of a kind commercial scale projects.
- The difficulties associated with financing a project without government backing. Also the cost and use of the CO_2 byproduct and its competitiveness with other CO_2 production sources.
- AEP's rationale surrounding its decision to suspend the Mountaineer CCS project.

2. Executive Summary

This report provides a brief overview of the research and development pursued in the Phase I – Front-end Engineering and Design (FEED) effort of the Mountaineer Commercial Scale Carbon Capture and Storage (MT CCS II). Through the research, the project identified data required for updating the company's integrated resource model, and effectively evaluating the project's economic feasibility. Various inputs to AEP's evaluation include:

- Estimated capital expenses,
- Anticipated operations and maintenance costs,
- Cost of generating electricity following implementation and during operation of the CCS facility,
- Assumptions of legislative impacts,
- Consideration of optional CO_2 sources, uses and revenue streams
- Financial risk,
- Other elements

AEP initiated the FEED study in early 2010. The front-end engineering and design package incorporated knowledge gained and lessons learned (construction and operations related) from the Mountaineer Product Validation Facility and the design package also established the fit, form, and function of the project including design criteria, mass and energy balances, plot plans, general arrangement drawings, electrical one-lines, flow diagrams, P&IDs, etc. From this conceptual design package, the project was able to identify the inputs, and evaluate the impacts on AEP's business case. As Phase I was nearing completion, AEP expressed its intention to suspend the project following the completion of Phase I objectives. This decision was due to a lack of federal climate change legislation adversely impacting AEP's ability to fund it's cost share of the commercial scale project. Although the project was suspended, the project completed the Phase I conceptual design package and project definition so that the project could be resumed at any point in the future.

Discussion of the issues associated with financing a first of a kind CCS project and AEP's ultimate decision not to proceed with the project are enclosed in this report.

Previous reports provided to Global CCS Institute describe the MT CCS II project, including inter-related projects that preceded and led to the development of the MT CCS II project, such reports and their findings are not repeated herein. Please review the reports on the list of references in this report for awareness and/or refreshment of project specific and background information previously provided.

3. Introduction

The existing Mountaineer Plant began commercial operation in 1980. The plant consists of a 1,300-MW pulverized coal-fired electric generating unit, a hyperbolic cooling tower, material handling and unloading facilities, and various ancillary facilities required to support plant operation. The plant uses (on average) approximately 10,000 tons of coal per day. Coal is delivered to the plant by barge (on the Ohio River), rail, and conveyors from a nearby coal mine located west of the site. The plant is equipped with air emissions control equipment, which includes: (1) an electrostatic precipitator for particulate control; (2) selective catalytic reduction for nitrogen oxides (NOx) control; (3) a wet flue gas desulfurization (FGD) unit for sulfur dioxide (SO_2) control; and (4) a Trona injection system for sulfur trioxide (SO_3) control.

Early in 2010, AEP entered into a cooperative agreement with the U.S. Department of Energy (DOE) to design, build, and operate a commercial scale carbon capture and storage facility. The MT CCS II project's primary objective was to capture 90% of the CO_2 from an approximate 235 MWe slip stream using the Alstom Chilled Ammonia Process (CAP) system. As the technology name implies, the CAP uses an ammonia-based reagent to capture CO_2 and isolate it in a form suitable for geologic storage. The captured CO_2 stream is cooled and compressed to a supercritical state for pipeline transport to the injection well sites in deep saline reservoirs.

The MT CCS II project was planned as a phased execution strategy which allowed AEP's management the opportunity to evaluate the financial and commercial feasibility of the project at various points and thus reduce the company's risk. The project was divided into four phases defined as: Phase I - Project Definition, Phase II - Design & Permitting, Phase III – Construction & Start-up, and Phase IV – Operations.

Phase I - Project Definition, included resolution of outstanding conditions with the Department of Energy (DOE) cooperative agreement, front-end engineering and design, initiation of the National Environmental Policy Act (NEPA) process, and identification of exceptionally long lead time items. The front-end engineering and design package incorporated knowledge gained and lessons learned from the Mountaineer Product Validation Facility (PVF). The front-end engineering and design package also established the fit, form, and function of the project including design criteria, mass & energy balances, plot plans, general arrangement drawings, electrical one-lines, flow diagrams, P&IDs, etc. *Phase II - Design & Permitting,* would have included detailed engineering and design, permitting activities, refinement of cost estimate, design review board meetings, finalization of project scope, procurement activities, site preparation activities, and injection well construction. *Phase III – Construction & Start-up*, would have included construction, start-up and commissioning, and initial performance testing of the CO_2 capture and storage systems. *Phase IV – Operations,* would have correlated to DOE's Operations, Data Collection, and Reporting Phase and included DOE required data collection and reporting associated with the initial four years of project operation and subsequent two years of post injection monitoring of the storage system.

4. Financial Modeling of CCS

AEP periodically updates its integrated resource planning model (IRP) to evaluate the timing for and types of new power generating units needed to serve the anticipated electric loads in its service territories. Inputs to the IRP include the costs of retrofitting, retiring, or replacing existing electric generation units and future legislative impacts. Potential federal carbon legislation impacts are based on assumptions related to the timing and cost of carbon emissions, likely capital costs for installation of the technology, and expected operations and maintenance costs.

AEP has relied on its own research and other third party experts for defining its assumptions related to future costs for carbon legislation. With the experience gained from installing Alstom's chilled ammonia process (CAP) technology at a 20 MWe scale pilot facility and the completion of front-end engineering and design for a 235 MWe commercial scale facility, AEP has a better understanding of the capital and operation and maintenance costs for a first of a kind CCS retrofit facility.

4.1. Development of Cost Estimate

The front-end engineering and design package developed for the MT CCS II project established the fit, form, and function of the project including design criteria, mass & energy balances, plot plans, general arrangement drawings, electrical one-lines, process flow diagrams, P&IDs, etc. From the front-end engineering and design package, the integrated project team, which included representatives from AEP, Alstom, Battelle, and Worley Parsons, developed a detailed, bottom-up cost estimate which encompassed the completion of Phases 1-4 Additional details regarding the development of the cost estimate are discussed in the front-end engineering and development report prepared for Global CCS Institute.

Shown in Table 1 below, is a listing of major cost line items comprising the total project estimate at completion for all phases of the Project (Phases I – IV). This includes an $825-million overnight cost estimate (2011 $USD) for the engineering, procurement, construction, start-up and fine tuning of the carbon capture and storage system retrofits, and $71-million of escalation to account for the time value of money as-spent over the project life. A risk based evaluation of the cost estimate was also performed that determined a need to add up to $103 million of contingency funding to the estimate. The contingency funding identified is to account for the uncertainties associated with the permitting and construction of the CO_2 storage system, volatility of projected escalation, and potential labor overtime during the construction and commissioning phase. The Phase IV operations, spanning September 2015 through June 2019 includes an estimated $66-million for operations, maintenance and consumables. The total project upper cost limit estimate of $1.065 billion represents an approximate 99.5% level of confidence that the project will meet or under run that amount.

System (Phases I, II, & III)	Estimate ($ million USD)
Capture System	$665
Storage System	$160
Sub-total (Overnight Cost)	**$825**
Escalation	$71
Risk Based Contingency	$103
Total Constructed Cost Range, Phases I-III	**$896 - $999**
Phase IV Operations	$66
Total Project Expected Cost Range, Phases I-IV	**$962 – $1,065**

Table 1: Project Cost Estimate

4.2. Consideration of Optional CO_2 Sources, Uses and Revenue Streams

In addition to understanding the project impacts on the cost of electricity, it is valuable to understand the various uses of captured CO_2. Shown in Figure No. 1 below is a diagram that illustrates the various uses for captured CO_2.

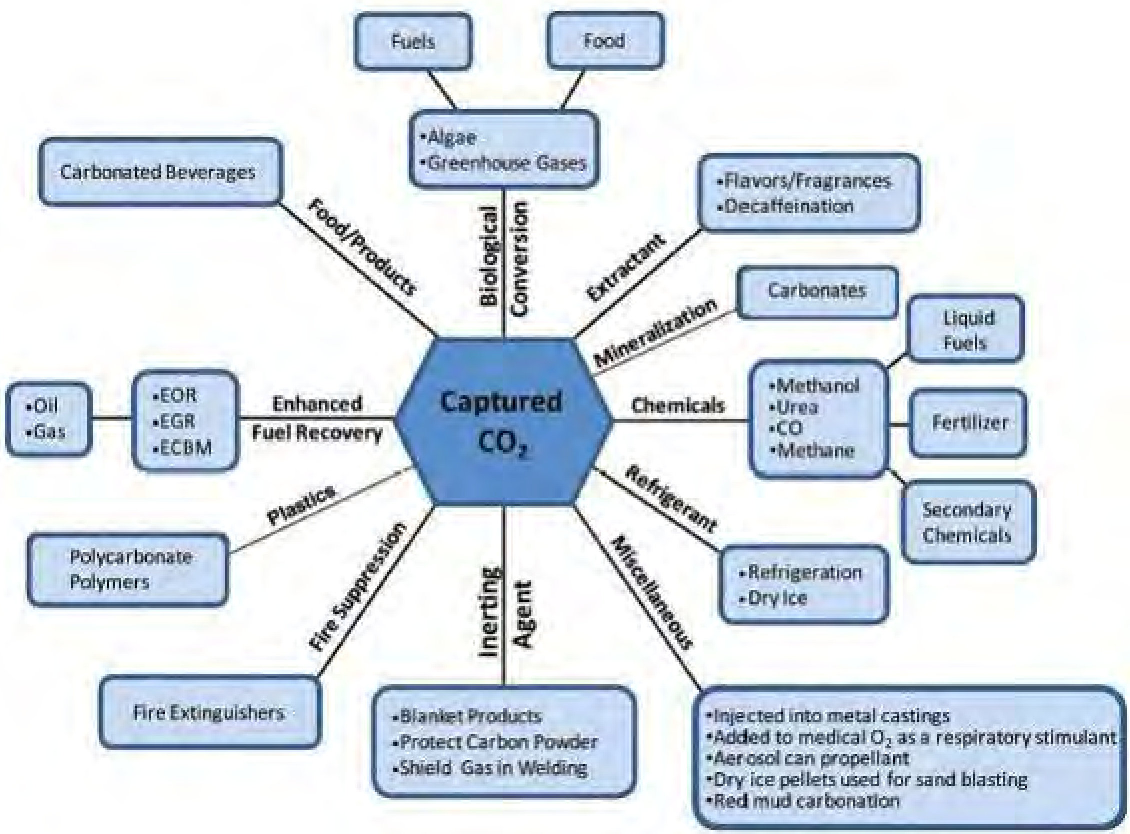

Figure No. 1 – Schematic Illustrating the Uses of CO_2

Of all the potential uses, AEP only considered the possibility of Enhanced Oil Recovery (EOR) having any real potential economic value to its analysis of CCS economics. AEP has determined that while it's possible that EOR can have a positive impact on CCS project economics, the use of CO_2 captured from power generation sources is more expensive than other, existing sources of CO_2. Shown in Table No. 2 below are estimated costs of CO_2 captured from various alternative sources. Carbon capture from industrial applications consists of proven technologies and will provide lower cost CO_2 than from power generation sources.

		Power Generation				Industrial Applications			
		AEP	*Harvard Report*	<---------------------------------*GCCSI/WorleyParsons*--------------------------------------->					
		Retrofit PC Supercritical (1)	PC Supercritical	PC Supercritical & Ultra Supercritical	NGCC	Blast Furnace Steel Production	Cement Production	Natural Gas Processing	Fertilizer Production
Cost of CO2 Captured ($/tonne CO2)	First of a Kind	176	100-150	53-55	90	49	49	19	20

Notes:
GCCSI - Summary of Table Produced

1. Based on a 20% IRR. The capital cost estimate to retrofit a 650 MW PC plant in the SPP market is $3 Billion (up from $1.2 Billion in past estimates).

Table No. 2 – Ranges of CO_2 Capture Costs from Select Sources

AEP estimates that a subsidy of $2.5 billion USD, (capital cost) on a 650 MW facility will be required to reduce the cost of CO_2 for EOR to $40/tonne which would result in an IRR of 20% over 30 years.

4.3. Local Economic Impacts of CCS

AEP does not independently factor in local economic impacts of projects when it runs financial models for integrated resource planning of future new generating units or retro-fit of existing generating units as these are assumed to be considered in commodity forecasts for energy, capacity, fuel and emissions. Independent, local economic benefits may be considered by the regulatory entities that are tasked to review and approve capital project expenditures. Listed below are some of the local economic benefits expected with the construction and commercial operation of a CCS project.

- Additional plant staffing - The cost estimate for operating and maintaining the MT CCS II project in phase IV anticipated the addition of 36 full time equivalent positions.
- Temporary local economic benefits derived from facility construction – For example, construction craft personnel are employed either directly from the local communities, which provides additional tax revenue for the community, or are sourced from a distant community and they must arrange for local accommodations.
- Property and/or Income Tax Revenues – Localities benefit from higher property tax valuations and/or from local income taxes derived from permanent employment created in the locality.
- Preservation of coal industry jobs – The coal industry and its supply chain provide vital economic benefits to the states located in regions with recoverable coal resources exist.

The local economic impacts of CCS projects will be better understood with the operations of the first commercial scale facilities.

4.4. Cost of Electricity

Upon completion of the estimates for construction and ongoing operations, AEP applied the cost projection for the MT CCS II project to AEP's financial analysis model. This analysis takes into account various aspects of retrofitting a 1300 MW Coal-fired unit with an 18% (235 MW) CCS facility including capital costs, fuel expenses, operations and maintenance costs, as well as cost of the parasitic load the CCS facility requires from the generating facility. In addition, a carrying charge which includes return of and on capital, depreciation, taxes and administrative costs which is applied to all capital expenditures. The outcome from this analysis, suggests that the MT CCS II project would increase the cost of electricity by approximately 80% above its current cost without CCS.

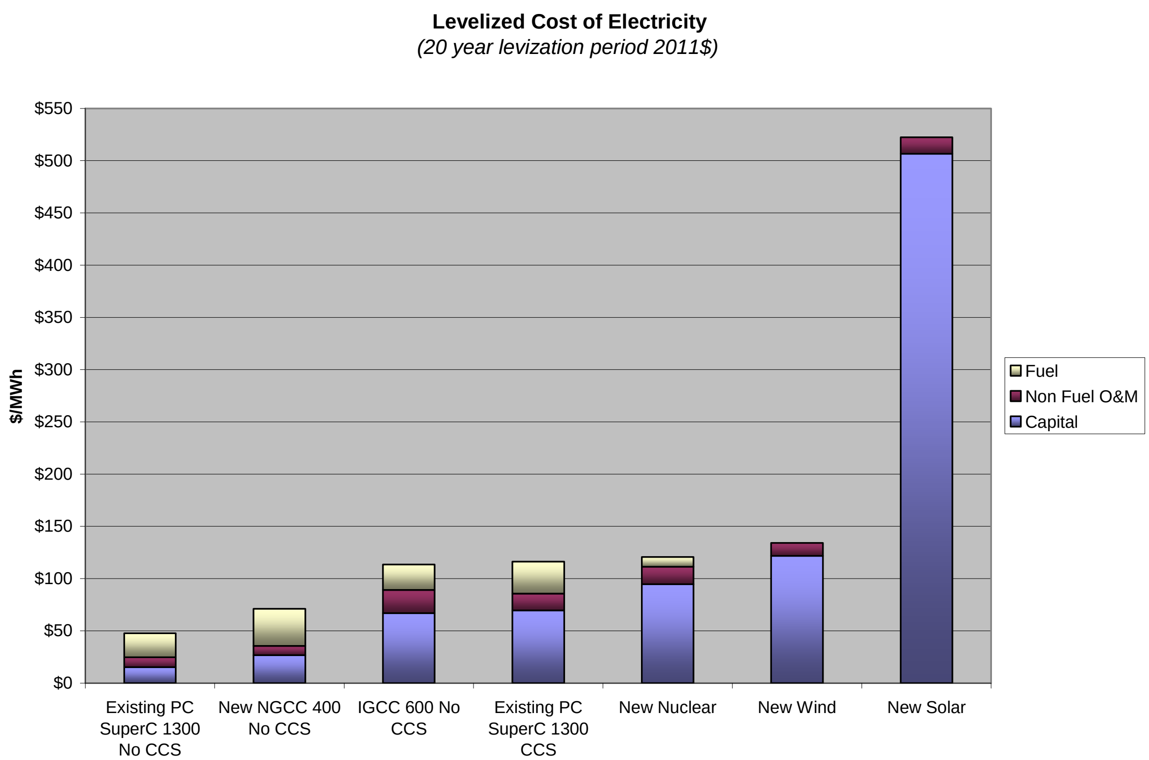

Figure No. 2 - Illustration of Levelized Cost of Electricity

5. Financial Risks

AEP's consideration of financial risk for the MT CCS II project is framed in the context of the company being an investor owned utility. AEP has an obligation to generate and/or deliver electric power to customers in predefined service territories. The obligation to serve is conditioned on the expectation that the company will continue to make prudent investments to support the reliable and cost effective delivery of electric power to its customers. In return, the various jurisdictions are expected to allow AEP to recover its reasonable operating and capital expenses, including a fixed rate of return on its capital investments. Investments and/or expenses not deemed prudent or in the interests of AEP's customers may not be eligible for cost recovery. Without cost recovery AEP has limited ability to fund costly first of a kind commercial demonstration projects without adversely impacting future net income and cash flow, which in turn affect its ability to fund other necessary investments.

5.1. Financial Risk Approach to New Retrofit Technology

High risk and first of a kind projects and/or programs need to be carefully managed during inception, testing, and commercial demonstration. Given its long history of innovation, AEP took a leadership role in exploring the feasibility of retrofitting its coal-fired fleet with carbon capture and storage technologies. In 2003, AEP first engaged in a cost sharing agreement with the DOE to determine the geologic feasibility of storing CO_2 in deep saline reservoirs in the Ohio Valley, which lead to the selection of Alstom's CAP technology for pilot testing of carbon capture and storage in the PVF project. The scale up of Alstom's CAP technology to a commercial scale project, which appeared to have AEP's financial commitment in-sync with emerging US policy for limiting CO_2 emissions, was intended to give a better understanding of both the technical and financial viability of retrofitting coal-fired generation with carbon capture and storage technology.

For the Mountaineer CCS II project, AEP and the DOE planned a phased approach to its execution with key decision points and phase gate off-ramps inserted at the end of each of Phases I & II. The decision points, allow for reflection of the work performed (e.g. technical and financial feasibility) within the phases and decisions on whether to proceed with subsequent project phases.

5.2. Risk of Impact to Reliable Plant Operations Due to CCS Retrofit

As discussed in the CCS Integration Report to the Global CCS Institute, AEP took a rather conservative approach to CCS integration in the conceptual design. This approach was due in part to the fact that this project would be the largest commercial scale application of this technology, and also that integration opportunities often add complexity, cost, and may not be practical with respect to potential impacts to the existing plant. Temporary loss of 1300 MW of electric generation to due to an adverse impact from a CCS retro-fit installation was considered unacceptable.

5.3. Need for Financial Incentives

As initial first of a kind commercial CCS projects are significantly more expensive than successor installations, governments can and should play a role in advancing retrofit technologies that support and advance a country's overall energy policy direction.

The U.S Department of Energy established the Clean Coal Power Initiative (CCPI) in 2002 as a cost-shared collaboration between the Government and industry to increase investment in low-emission coal technology by demonstrating advanced coal based, power generation technologies. The CCPI goal is to accelerate the readiness of advanced coal technologies for commercial deployment, thus ensuring that the United States has clean, reliable, and affordable power. By overcoming technical risks associated with bringing advanced technology to the point of commercial readiness, the CCPI accelerates the deployment of new coal technologies for power and hydrogen production and, contributes to proving the feasibility of CO_2 management integration and facilitates the movement of technologies into the marketplace that are emerging from core research and development activities.

Round three of the CCPI sought cooperative agreements between the Government and industry to demonstrate on a commercial scale, new technologies that capture carbon dioxide emissions from coal-fired power plants and either sequester the CO_2 or put it to beneficial use. The goals are to demonstrate technologies that (1) can achieve a minimum of 50% CO_2 capture efficiency and make progress toward a target CO_2 capture efficiency of 90% in a gas stream containing at least 10% CO_2 by volume, (2) make progress toward capture and sequestration goal of less than 10% increase in the cost of electricity (COE) for gasification systems and less than 35% for combustion and oxy-combustion systems all as compared to current (2008) practice, and (3) capture and sequester or put to beneficial use a minimum of 300,000 tons per year of CO_2. The Mountaineer Commercial Scale CCS Project described in this report was funded under Round Three of the DOE's CCPI.

The Mountaineer commercial scale CCS project was funded at a 50% cost share. The 50% cost share would reduce the initial cost of a first of a kind facility to a level that would be expected to be below what a following like kind facility would otherwise be eligible for cost recovery, given a federal mandate. Without a federal mandate, the project, which is too costly to be funded solely by investor owned electric utilities, would need governmental assistance or cost sharing approaching 80% or more, depending on the specific circumstances of the investor owned utility and/or consortium of utilities.

5.4. Current Financing Environment

On July 14, 2011, AEP announced its intentions to suspend CCS efforts following the completion of the Phase I scope, citing a weak economy and the "uncertain status of U.S. climate policy." CEO Morris said AEP and its partners "have advanced CCS technology more than any other power generator with our successful two-year project to validate the technology. But at this time it doesn't make economic sense to continue."

The business case for carbon capture and compression from power generation sources is not promising without changes in areas such as Federal carbon legislation, the cost and efficiency of carbon capture technology, long term oil and natural gas prices and long term geological storage issues.

AEP estimates that commercially available power generation capture and compression technology likely will not be available for 10 to 15 years. Given the projected demand for CO_2 for various processes referred to in Figure 1, it is expected that the incremental revenues generated from CCS are far too low to cover the high costs of building and operating the CCS technology from power generation facilities. These risks make it difficult to attract participation from the institutional and private investment communities making government backed loan guarantees the only affordable option.

AEP sought to recover a portion of its CCS pilot costs by filing a $74 million rate increase in Virginia. The reply was a brusque no. “There are currently no laws mandating carbon capture,” stated a brief from the Virginia Attorney General’s office, which advocates on behalf of consumers. “Any potential benefit is speculative and outweighed by the enormous cost of the pilot project.” The rebuffs more than stung, says AEP President Nick Akins. “This stuff is very expensive to do,” says Gary O. Spitznogle, AEP’s director of new technology development. “Without a regulatory mandate, you won’t see utilities deploy this.”

Since the beginning of the fourth quarter of 2010, at least five large-scale CCS projects have been canceled or postponed including the ZeroGen project in Queensland, Australia where the goal was to create a 530 MW coal plant that captured and buried its CO_2 emissions underground, and the Vattenfall project in Jaenschwalde, Germany which was to capture 1.7 million tonnes of CO_2 annually.

6. Conclusions

As previously stated, AEP and its extended project team successfully completed the Phase I effort for the MT CCS II project, as outlined in the U.S. DOE cooperative agreement. Within Phase I, the cooperative agreement called for project specific developmental activities (i.e., front-end engineering & design); the initiation of the NEPA process; and the identification of exceptionally long lead time items. The front-end engineering and design package developed within Phase I incorporated knowledge gained and lessons learned (construction and operations related) from the Pilot Validation Facility and also established the fit, form, and function of the project including design criteria, mass and energy balances, plot plans, general arrangement drawings, electrical one-lines, flow diagrams, P&IDs, etc.

Based on the work completed in the front-end engineering and design package, AEP and its extended project team also:

- Developed a +/- 25% cost estimate,
- Developed a detailed Phase II project schedule,
- Provided DOE with all information it needed to complete the NEPA process,
- Developed a multi prime construction contracting strategy for Phase III,
- Issued preliminary PFD and overall mass and energy balances, and
- Completed preliminary project design.

The work completed in Phase I continues the advancement of Alstom's CAP technology toward demonstration at the commercial scale. Additionally, the information developed during the Phase I effort provided a solid understanding of the commercial scale CCS facility utilizing the chilled ammonia process and enabled AEP to perform a quantitative evaluation of the project and its impact on the company's business case.

At the current time, the business case for carbon capture and compression from power generation sources is not promising without changes in various areas. The long term viability of CCS in the US will however be dependent on future federal legislation and comparison of the incremental costs of CCS retro-fit technologies for the production of electricity relative to competing fuel sources.