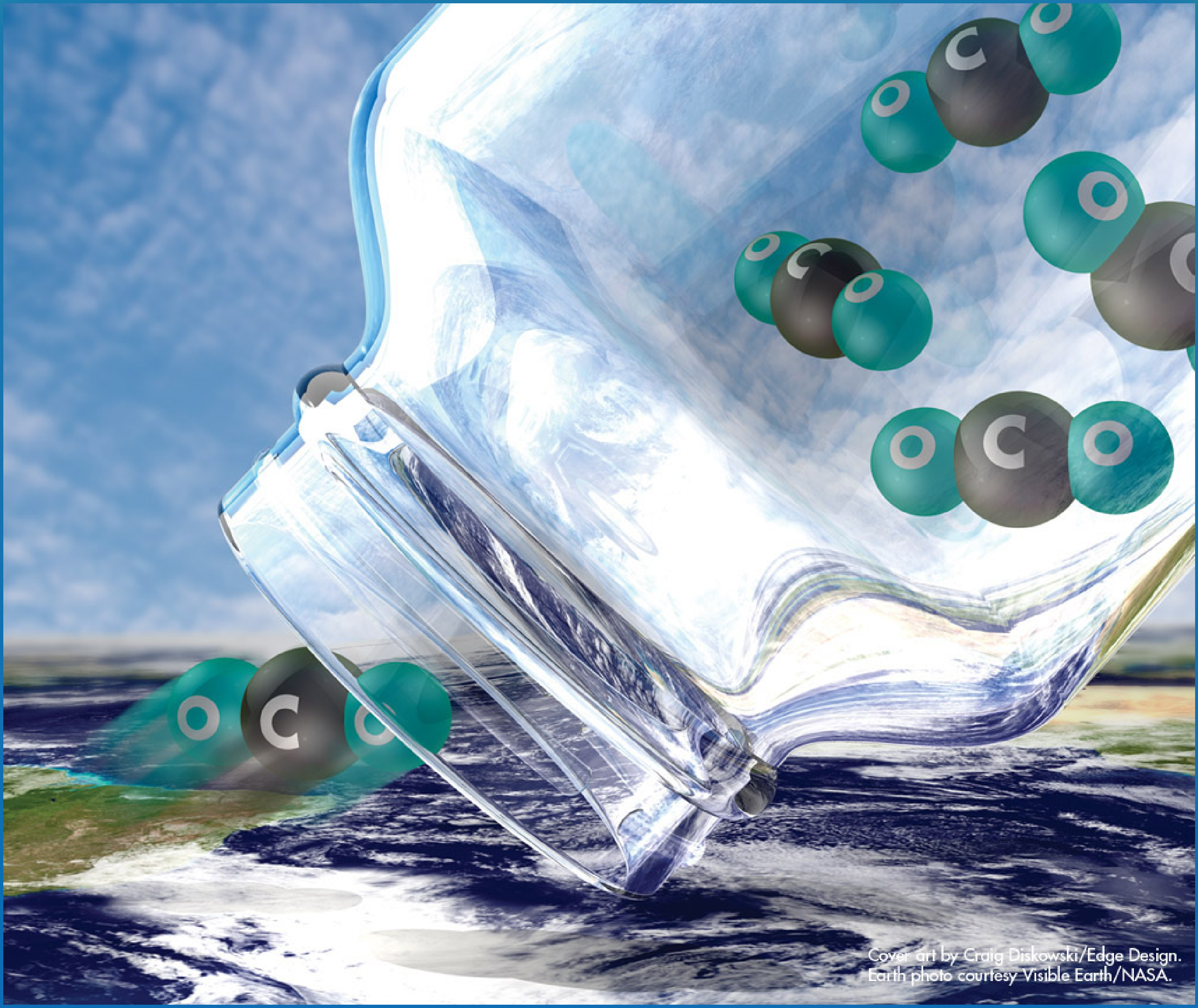
EPRI Post-Combustion CO_2 Capture and Storage Demonstrations

Overview, Value, and Deliverables



Overview

The Electric Power Research Institute, Inc. (EPRI) has examined current and potential options for reducing greenhouse gas (GHG) emissions from the electric sector. EPRI's analysis shows significant potential carbon dioxide (CO_2) reduction from advanced coal power systems that include CO_2 capture and storage (CCS) technology, making such systems likely to be an essential component of a full portfolio of GHG reductions strategies[1]. However, CCS technology is not yet commercially available, and implementation of the portfolio must start now to achieve likely goals for reducing GHG emissions by the year 2020[2]. EPRI has formed a collaborative to support two CCS demonstration projects:

- ***American Electric Power Service Corporation (AEP) Demonstration Project:*** This project scales up Alstom's chilled ammonia process from the current 1.7-MWe field pilot in Wisconsin to a 20-MWe (~100,000 tonnes [110,000 tons] CO_2/yr) pre-commercial "product validation facility" (PVF) at AEP's Mountaineer Plant. Storage of the CO_2 will be done via injection into two on-site wells. The chilled ammonia capture system started up in September 2009 and will operate one to five years.

- ***Southern Company (SoCo) Demonstration Project:*** This project will deploy the Mitsubishi Heavy Industries, Ltd KM-CDR™ advanced amine CO_2 capture technology at SoCo subsidiary Alabama Power's Plant Barry. It will evaluate the integration of CCS at about 25 MWe (~125,000 tons [115,000 tonnes] CO_2/yr). Design of the injection and storage portion of the project is under way in conjunction with U.S. Department of Energy (DOE) under its Southeast Regional Carbon Sequestration Partnership Program (SECARB) Phase III. The SoCo project is scheduled to start up in early 2011, following completion of the flue gas desulphurization (FGD) retrofit to the host site.

Both projects are expected to be completed by 2014 (excluding post-injection monitoring). These CCS demonstrations are part of a larger power industry-driven EPRI collaborative program of proposed projects for critical-path CO_2-reducing technologies. EPRI's role is to provide design features and tests and evaluate project progress and achievements to help bring the technology to a stage in which it can be used to benefit the power utility industry and the public.

The interrelated schedule for these projects is shown in **Figure 1**. The figure shows estimated timelines for: pilot programs, which are early deployments of technology on a smaller scale; demonstration projects, which are larger-scale validations of technology; and plant integration, when the vetted technology is integrated into a commercial plant at full scale. By managing risk through staged development and shared costs among collaborative funders, EPRI's demonstrations are designed to help usher coal-based technologies into the next phase of commercial deployment.

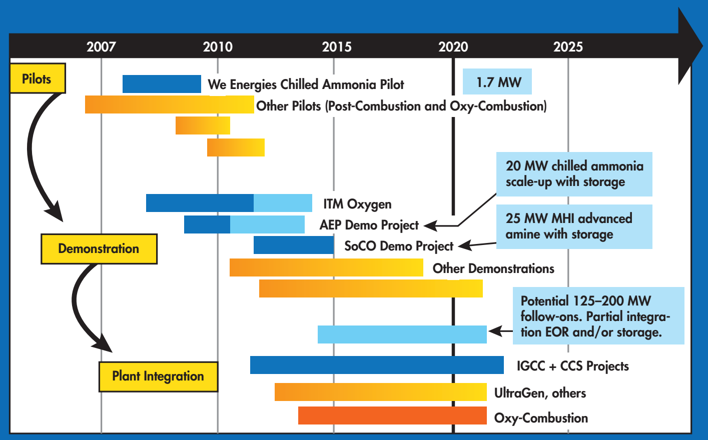


Figure 1. EPRI's Proposed CCS Demonstration Projects Timeline
CO_2 storage formations will be monitored for at least two years after the end of injection and the results reported to the collaborative

The primary objectives of the AEP and SoCo demonstration projects are to simultaneously advance the development of post-combustion CO_2 capture technologies; obtain first-of-a-kind experience in compressing and transporting CO_2 derived from coal combustion; and expand industry and public knowledge and understanding of the feasibility of underground storage of captured CO_2.

These projects will help define both retrofit and new generation options for post-combustion capture. Their strategic importance is the early demonstration, at power plant scale, of integrated CCS processes and in their pioneering roles in advancing public, regulatory, and industry understanding of geologic storage.

This document provides more details about the deliverables and value statements for collaborative funders presented in EPRI Supplemental Project Notice (SPN) 1018740, "Large-Scale Post-Combustion CO_2 Capture and Storage Demonstrations." **Any and all deliverables, value statements, and activities described in this document and the SPN are subject to EPRI's final agreements with hosts and/or technology vendors.**

1. *Advanced Coal Power Systems with CO_2 Capture: EPRI's CoalFleet for Tomorrow Vision*, EPRI, Palo Alto, CA: 2008.
2. *The Power to Reduce CO_2 Emissions: the Full Portfolio*, Discussion Paper by EPRI Energy Technology Assessment Center, EPRI, Palo Alto, CA: August 2007.

Capture

These two projects are among the earliest of a number of integrated CCS demonstrations planned worldwide. EPRI expects that, at the end of these two projects, collaborative funders will be able to better judge the adequacy of the proposed designs and performance objectives from at least two capture process suppliers through the information obtained on emissions (all media and pollutants), consumables, energy (how much energy, what form, and at what state conditions) and possibilities for thermal integration into a given power plant, the tradeoffs between emission reductions and energy/reagent consumption, and plant operability and reliability.

These data will be communicated on an ongoing basis to collaborative funders through quarterly webcasts and annual site visits, providing them early insights into these technologies and their potential further improvements, developments, and remaining challenges. Results from environmental and performance tests conducted periodically throughout the project during periods of stable operation will be summarized in reports and used by EPRI to prepare an independent technical and economic evaluation of each process as it might be applied to a representative new 750-MW supercritical power plant. Consideration will also be given to retrofit applications. These technical and economic evaluation studies will be performed following the first two years of operation of each capture system.

Storage

EPRI will provide different levels of information for each project, given its unique involvement in each. At both sites, EPRI will provide design and operating data on the compressor and possibly the transport line as part of the storage reports. Collaborative funders will be provided information on storage aspects throughout the project up to the end of the post-injection monitoring.

The information from the AEP demonstration project will include lessons learned from the well design, permitting process, and extensive performance data obtained during the operation of the storage process. The pre-injection phase is complete – the drilling and injection permits have been obtained and the two injection wells and three monitoring wells have been drilled and completed. Injection operations started on October 1, 2009. Collaborative funders will receive the operation, performance, and monitoring (including post-injection) data AEP is required to provide its regulatory authorities under its Underground Injection Control (UIC) permit[3].

EPRI is directly managing the entire storage phase of the SoCo demonstration project and will provide its collaborative funders, on an ongoing basis, details of the process from site selection to permitting and associated interface with the public, actual injection/storage, and eventual site closure and post-closure monitoring. This phase of the SoCo project is 75% funded by the DOE, which requires extensive reporting. Collaborative funders will receive this information in near-real time, along with substantial detail and ongoing assessment of its meaning and implications. DOE's public reports typically appear later.

PROJECT VALUE

These demonstrations provide EPRI's collaborative funders with the benefits indicated below, and the opportunity to advise on EPRI's involvement in the two projects. This ensures that EPRI is obtaining the information needed by the collaborative funders (within the constraints established by the capture process suppliers and/or hosts and available resources).

Capture Technology

- Collaborative support means there is greater probability that at least two capture processes will have been demonstrated beyond the research scale by the time power companies select their technologies for the first several commercial installations.

  — Until these projects, CO_2 capture technologies had not been demonstrated on a coal-fired power plant, other than the very expensive and energy-consumptive monoethanolamine (MEA) process.

  — Political observers anticipate that power companies may have to begin installing CCS around 2020, hence selection around 2017.

  — Development cycles for such complex equipment are long, so 2017 means demonstrations at this scale (approximately 1/10th full-scale) are needed now.

  — To EPRI's knowledge, these two projects currently are the only ones in which the evaluating entity is an independent, third-party organization, and is engaged neither by the capture process supplier nor the host that has selected the technology for demonstration.

3. West Virginia Department of Environmental Protection UIC permit

- Near-real-time results will give collaborative funders early information to help determine which CO_2 capture process(es) to select for their first commercial installations. If one or both of these processes demonstrate the ability to meet project objectives, and a participating power company selects one of them, that company will reduce the risk typically associated with being an early adopter.

- Understanding the development path of the technology, and having the opportunity for significant interaction with these two capture process suppliers and users (both AEP and SoCo have large, highly qualified engineering groups), grounded in an in-depth understanding of the process, should enable each collaborative funder's advanced technology engineers to proactively evaluate their company's options and better understand the technologies of all vendors of solvent-based CO_2 capture systems. In addition to learning specifics about the chilled ammonia and advanced amine processes being demonstrated, collaborative funders will gain further insights into the broader area of CO_2 capture by solvents.

Storage Process

- Early indications of what is needed, what works, and what doesn't work (at least in terms of the geologies, permitting agencies, and public attitudes of the two project locations) when seeking an underground injection permit for CO_2 storage can be valuable information both for satisfying regulatory requirements and building public understanding. Participating companies can decide how to adapt these experiences and use what they've learned early enough to adjust their own strategies before facing a deadline.

- Insights into the injectibility of large quantities of CO_2 in two very different geologies, and how the behavior of those formations compares to the predicted behavior, can be applied to similar programs elsewhere.

- Early information on successful site selection; well design; and measurement, monitoring, and verification approaches can be used by collaborative funders (e.g., selection of the measurement techniques for site selection that appear to provide the most reliable results) to help guide similar efforts for their own power plants.

- Ability to advise EPRI in its evaluation of compression and transport issues, especially materials issues – e.g., what contaminants in the CO_2 stream may be accept able -- means collaborative funders can ensure that the materials of construction commonly used in its locale/ country are considered by EPRI.

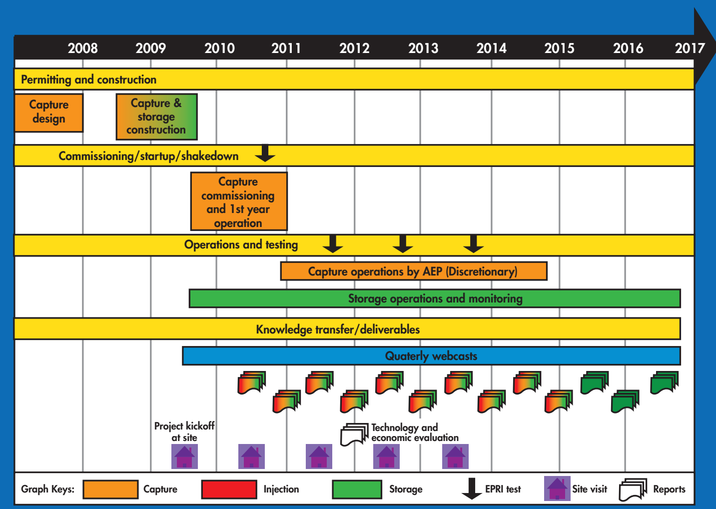


Figure 2. Proposed AEP Post-Combustion CCS Project Timeline
(Injection schedule is same as capture schedule; monitoring reports will be provided for at least two years after injection ceases, or 2017, whichever comes first.).

- Similarly, the ability to advise EPRI to investigate compression technologies and/or storage approaches being considered in a participating company's country, if different than the technologies already being evaluated by EPRI, can ensure R&D is applicable to collaborative funders.

DELIVERABLES

In collaboration with the two host companies and their capture process suppliers, EPRI plans similar but separate deliverables and information transfer activities for each project. These are summarized in **Table 1a** (AEP demonstration project) and **Table 1b** (SoCo demonstration project) below. An overall proposed schedule for the AEP demonstration project is given in **Figure 2**. The overall proposed schedule for the SoCo demonstration project would be similar, starting about 1-1½ years later.

Table 1a. Communication Plan for AEP Demonstration Project

Item	Key Content	Timing
Meetings and Webcasts		
Kickoff meeting and site visit	Provide the schedule and plan for moving forward, get the collaborative funders fully up to date on the project, and provide a site visit following commissioning.	Fall 2009
Webcasts	Project status, issues/resolution (technical and programmatic), performance results (emissions, energy use, operability, etc.). Primary focus on capture processes, but will include available data or experiences on storage (e.g., exceptions to expected injectivity, pressures, mechanical equipment performance).	Quarterly, starting 3 months after kickoff meeting
Site visits and project review meetings	In-depth technical updates, observations of capture process operation, and opportunities for in-depth dialogue with demo team	During the kickoff meeting, then once per year throughout the capture and injection phase of the project
Reports		
Operation and performance reports on capture project	Performance (emissions, energy, etc.), operability, reliability, maintenance. Detailed after first year of operation (multiple EPRI test campaigns + on-site observer); updates thereafter, if applicable, (1 EPRI test campaign/year + access to operational experience).	Annually
Injection performance reports	Quantity CO_2 injected, pressures, events, materials inspections for corrosion, results of underground drinking water samples.	Semi-annually, starting around mid-2010
Injection and storage performance reports	Semi-annual report content + monitoring-well fluid analyses, modeling updates, CO_2 footprint, well integrity and maintenance.	Annually, starting early 2011
Technical/Economic evaluation of capture system	Performance (emissions, energy, consumables, etc.), plant thermal integration opportunities, economics, other factors (e.g., space), as applied to a commercial-scale plant.	After second year of CO2 capture operation, if applicable
Post-closure storage report	Post injection CO_2 footprint, down-hole pressures, other monitoring results (results of underground drinking waters samples, results of vadose zone monitoring (tentative)).	One to two years after post-injection

Table 1b. Communication Plan for SoCo Demonstration Project

Item	Key Content	Timing
Meetings and Webcasts		
Kickoff meeting and site visit	Provide the schedule and plan for moving forward, get the collaborative funders fully up to date on the project, and provide a site visit.	Fall 2009
Webcasts	Project status, issues/resolution (technical and programmatic), performance results (emissions, energy use, operability, etc.). Primary focus on capture processes, but will include available data or experiences on storage (e.g., exceptions to expected injectivity, pressures, mechanical equipment performance).	Quarterly, starting 3 months after kickoff meeting
Site visits and project review meetings	In-depth technical updates, observations of capture process operation, tours of compressors and injection location, opportunities for in-depth dialogue with demo team.	During the kickoff meeting, then once per year throughout the capture and injection phase of the project.
Reports		
Operation and performance reports on capture project	Performance (emissions, energy, etc.), operability, reliability, maintenance. Detailed after first year of operation (multiple EPRI test campaigns + on-site observer); updates thereafter (1 EPRI test campaign/year + access to operational experience).	Annually
Storage briefings	Summary of important results occurring during the previous month, in bullet form	Monthly after start of injection
	PowerPoint summary of important results during the period	Quarterly
Storage reports	Written report summarizing important results	Semi-annually
Final report	Written report summarizing all of the storage work and results, including summary of all of the deliverables	Within 6 months of the end of the project
Technical/Economic evaluation of capture system	Performance (emissions, energy, consumables, etc.), plant thermal integration opportunities, economics, other factors (e.g., space), as applied to a commercial-scale plant	At end of second year of CO_2 capture operation

Kickoff Meeting

A kickoff meeting will occur in 4th quarter 2009 to introduce collaborative funders to project personnel (host, capture process supplier, storage contractor, and EPRI), confirm project objectives, and provide a plan for moving forward. The discussion will include schedule and deliverables, an up-to-date status report on the CO_2 capture process as it will be tested during the demonstration, and an opportunity to visit the site.

Webcasts

EPRI and its partners (host, capture process supplier, and storage contractor) will host quarterly webcasts to provide collaborative funders information on the status of the project and technical updates on (a) the CO_2 capture system performance, challenges encountered and their resolution; (b) any operational issues in the compression and transport system; and (c) performance of the CO_2 injection and plume monitoring efforts. The actual data provided during each webcast will depend on the activities and tests conducted during that quarter; thus, webcasts during start-up and commissioning of the capture system might focus on key parameters such as CO_2 capture and solvent slip, while later webcasts could include energy requirements and reliability. Over the duration of the project, the information shared with the collaborative funders will cover the items delineated in **Table 2**.

Site Visits

Site visits will occur once per year throughout the capture and injection phase of the project. Site visits will be scheduled for the kickoff meeting; during one of EPRI's test campaign weeks in the first year of operation; and during or shortly after EPRI test campaigns in later years. The site visits will include project updates (as described under "Webcasts," above) and tours of the pilot CO_2 capture system, the compressors, transport lines, and injection sites. These site visits will provide the opportunity for more detailed technical updates, enabling collaborative funders to watch the system in actual operation and to interact with engineers from EPRI, the host company (both engineering and plant operations), and the capture process supplier (especially during the first year of operation, when both process design and operations staff from the capture supplier are expected to be on-site). Similar one-day visits were held in September 2008 and July 2009 at the 1.7-MWe chilled ammonia pilot at We Energies' Pleasant Prairie Power Plant and were very well-received by the attendees. During the site visits, EPRI expects to be able to share host and supplier experience with start-up and commissioning, transient behavior, operability, reliability, and maintenance requirements.

Capture Reports

Reports on the capture systems will be published as follows:

- Following the first year of operation of the capture system, EPRI will publish a report that presents the results of its test campaigns [4], its observations of the process operation, as well as the non-confidential information obtained from the hosts and capture process suppliers.

- Yearly thereafter, if applicable, EPRI will publish non-confidential updates, focused on its annual test campaigns to determine long-term performance, and the system operability, reliability, and maintenance requirements as observed by EPRI and/or obtained from the hosts.

- Following the end of the second year of operation (or the end of operation if earlier) of the capture system in each project, EPRI will publish its technical and economic evaluation of the process. The key contents of this report are identified in **Table 3**.

4. The test campaigns are the periods during which EPRI will conduct its independent testing of the process environmental, operational, and energy performance. They will be undertaken during periods of stable operation of the capture system.

Table 2. CO_2 Capture System Process Data (both demonstration projects)

Type	Process Information
Overview	• Process description • General arrangement diagrams • Project photographs • Test plans • Schedule
Design	• Process flow diagram • Equipment list
Coal data	• Coal properties (periodically)
Heat & mass balance	• Flue gas properties entering system (flow rate, temperature, pressure [if not addressed by system ΔP], gas composition, particulate loading and [occasionally] size distribution – concentrations and rates) • Any required pre-treatment of the inlet flue gas (e.g., additives, pH, corrosion inhibitors, etc.) • Flue gas properties exiting system – flue gas exhaust to stack and concentrated CO_2 stream • Make-up(s) (reagents, any other) and discharges/blowdowns (what, phase, properties/purities, rates, continuous or periodic, and temperature/pressure) • Thermal energy exchanges with power plant and environment (temperature of receiving or providing fluid, energy flux at each external interface • Total auxiliary power consumption for the process
Operational experience	• Reliability, level of automated operation, response to transients and trips, maintenance requirements, etc. • Foaming/fouling experience and remedies • Corrosion potential
Other	• General operating philosophies when integrating with the host plant • Commercial development schedule

Table 3. Information in Capture Process Engineering Economic Study (after one to two years of CO_2 capture process operation for each site)

Update based on prior EPRI studies for each process applied to a generic post-combustion plant with the following characteristics:
• Net capacity – 750 MW • Low-sulfur bituminous coal • Steam conditions: 4200 psia/1110°F/1150°F (290 bar/600C/620C) • Environmental controls for near-zero emissions and processes to minimize CO_2 capture system solvent losses. Conventional pollutant controls include low-NOx burners, SCR (de-NOx), dry electrostatic precipitator (ESP [electrofilter]), wet flue gas desulphurization (FGD [de-SOx]), and measures to achieve hazardous air pollutant limits expected to be promulgated by the U.S. Environmental Protection Agency (EPA) by that time. • Plant located in Kenosha, Wisconsin (considered typical site for economic analyses) using economic criteria from EPRI's Technical Assessment Guide (TAG). Allows comparisons with other EPRI studies. • Post-combustion capture (PCC) plant designed for 90% CO_2 capture, assumes a mature application (i.e., not burdened with large contingencies), and includes product CO_2 dehydration and compression. • CO_2 purity to satisfy transportation pipeline quality criteria as established in earlier EPRI studies.
Deliverables to include:
• Process description • Summarized process flow diagrams • Preliminary plot plan, with equipment functional relationships • Key equipment list • Heat and mass balances describing the liquid and gas flows entering and leaving the system • Water balances • Power plant interfaces and utility requirements • Total Plant Cost (TPC), budgetary capital costs, fixed and variable operating and maintenance (O&M) costs, net heat rate, and cost of electricity • Considerations for retrofitting CO_2 capture process to existing power plants.

Storage Reports

EPRI will provide collaborative funders with key performance results of this portion of each project. The information expected to be included in these updates is identified in **Table 4a** (AEP demonstration project) and **Table 4b** (SoCo demonstration project), and summarized below.

- For the AEP demonstration project, semi-annually as indicated in **Table 4a**. The post-closure reporting requirements have been determined by AEP and its regulators during the process of obtaining its injection permit.
- For the SoCo demonstration project, monthly, quarterly, and semi-annual updates, and a final report will be submitted as part of the DOE project. Each will contain results during the period it covers; topics expected to be covered in these reports are shown in **Table 4b**.

Table 4a. Storage Activity Data and Information Reports for the AEP Demonstration

Report Frequency	Information To Be Reported
Initial	• Copies of all permits from both the drilling and UIC permit processes • Detailed presentation of permitting experience during kick-off meeting
Semi-annually	• Monthly volumes of CO_2 injected and cumulatives to date • Monthly summaries (average, maximum, and minimum) of: — CO_2 injection pressure, temperature, and flow rate — Injection well annulus pressure — Bottom-hole temperature and pressure in injection wells and three monitoring wells • Descriptions of any events that trigger a shutdown of injection wells • Quarterly analyses of CO_2 stream chemical composition • Quarterly analyses/inspection of corrosion monitoring of well and pipeline materials • Quarterly groundwater monitoring of the underground source of drinking water (USDW) *Tentative* • Periodic (at times to be determined) vadose-zone soil gas monitoring for detection of CO_2 leakage
Annually	• Annual fluid monitoring of injection zone in all three monitoring wells • Annual cross-well seismic monitoring reports/data • Changes to the modeled/projected CO_2 footprint • Mechanical integrity tests following annual monitoring events (selected wells only) • Any updated model results • Any well maintenance performed • Any pressure fall-off tests performed on the injection wells
Post-injection monitoring	To be determined by injection permit, but at least: • Annual groundwater monitoring of the USDW • Changes to the modeled/projected CO_2 footprint • Any well maintenance performed *Tentative* • Periodic vadose-zone soil gas monitoring for detection of CO_2 leakage

Table 4b. Storage Activity Data and Information for the SoCo Demonstration

Report Frequency	Information To Be Reported
Before injection	• Assessment of existing subsurface data • Survey of existing wellbores in project area • Subsurface characterization for project site • Existing infrastructure and surface project suitability • Design specifications for initial reservoir modeling • Site implementation plan • Injection well construction diagrams and specifications • Observation well construction diagrams and specifications • Site design and layout • Transportation design and products specifications • Initial report on reservoir modeling • Completed National Environmental Policy Act (NEPA) questionnaire • Additional data and support for the environmental assessment (EA) or environmental impact statement (EIS) review • Summary report on background information for use in an EA or EIS review • Completed UIC permit document • Completed drilling permit • Design specifications for seismic survey • Permits for seismic and other site preparation • Completed and interpreted seismic survey.
Well drilling and injection	• Report on well integrity tests • Annual report on in-situ monitoring program • Initial injection period reservoir modeling report • Second injection period reservoir modeling report
Post-injection	• Post-injection period reservoir modeling report • Report on site closure and transfer • Preliminary report on post-injection surface and near-surface monitoring • Preliminary report on post-injection in-situ monitoring • Post-injection assessment report • Final report on reservoir modeling

CONCLUDING REMARKS AND CONTACT INFORMATION

These projects represent key elements in EPRI's strategy to see industry develop and deploy cost-effective advanced coal and CCS technologies. Meeting this challenge will help ensure that technologies are ready for widespread deployment after 2020 and can be compatible with energy affordability, energy security, and economic goals.

Contact Information

For more information on the **Large-Scale Post-Combustion CO_2 Capture and Storage Demonstrations**, please contact:

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SoCo Demonstration Project: Dick Rhudy at 650.855.2421 (rrhudy@epri.com)

Or contact the EPRI Customer Assistance Center at 800.313.3774 (askepri@epri.com).

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