

CO₂ Capture and Storage - Program 165

Program Overview

Program Description

According to EPRI's PRISM/MERGE analysis, carbon capture and storage (CCS) from electricity generation will be one of the largest contributors to the nation's goal of decreasing greenhouse gas (GHG) emissions in the near-to mid-term. For pulverized coal (PC) plants to provide competitively priced electricity while addressing climate change concerns, they must have access to CO₂ capture systems with acceptable costs as well as secure geologic storage. To achieve that goal, the industry needs capture processes with much lower parasitic plant loads and costs than systems available today; confidence in the ability to safely and permanently store large quantities of CO₂ in underground formations; and a legal and regulatory framework that is workable and technically sound.

EPRI's CO₂ Capture and Storage program (Program 165) provides information about the expected cost, availability, performance, and potential risks of a range of flue gas CO₂ capture processes. The program seeks and encourages the development of breakthrough post-combustion CO₂ capture technologies with substantially lower energy and cost penalties. In addition, the program determines purity requirements for the CO₂ stream discharged by the capture process to ensure compatibility with the compression, transport, and injection processes, and conducts the R&D needed to demonstrate the permanence, safety, and environmental acceptability of long-term CO₂ storage from any source.

Research Value

Substantial barriers must be overcome and technical and societal uncertainties must be resolved before CCS can be widely deployed, but time is growing short. Policy watchers have indicated that federal CO₂ limits could be imposed on all new plants put in service in the United States after 2020. Proposed PC plants already have been denied permits in the absence of firm plans to capture and store their CO₂ emissions. This program meets the industry's most urgent need—information for:

- Credible asset planning through early understanding of the options, development timelines, costs, technical uncertainties, regulatory issues, and related issues
- Increased confidence that acceptable capture technologies and storage options will be available when needed
- Use in public dialogue on the practical extent and timing of CO₂ reduction from U.S. power plants, using neutral third-party data and assessments from EPRI.

Approach

Parallel, complementary activities in post-combustion CO₂ capture and CO₂ storage—technical and economic assessments of EPRI-identified processes, followed by development and demonstration of the most promising—advance the availability of commercially mature carbon capture methods. Multiple, large, multi-year geosequestration projects provide the information and tools needed to gain public and regulatory acceptance of commercial-scale CO₂ storage. Topical studies (e.g., predicting and countering any environmental impacts of contact between injected CO₂ and potable aquifers) support the field injection demonstrations by addressing all the underlying geochemistry and structural interactions. Members receive this information through two Project Sets with three projects each:

Post-combustion CO₂ Removal

- "Technology Watch: CO₂ Capture" highlights developments and trends in carbon capture through periodic updates on worldwide post-combustion CO₂ capture research. Information is obtained through participation in the IEA Greenhouse Gas R&D Program and associated networks, the Massachusetts Institute of Technology's (MIT's) Carbon Sequestration Initiative, and workshops and conferences.

- Assessments of “add-on” CO₂ capture or fixation systems for combustion-based fossil power plants are collected in a database of CO₂ capture processes, with in-depth assessments of selected technologies. R&D also includes process simulations of the most promising technologies for further improvements through optimized design and thermal integration with the power plant, as well as accelerated development of promising new technologies. In addition, the program continues to co-produce economic studies of post-combustion CO₂ capture with different technologies and scenarios with the CoalFleet for Tomorrow Program (Program 66).
- CO₂ compression technology and transportation systems R&D summarizes the state-of-technology in large CO₂ compressors, with emphasis on technology developments and system integration approaches to minimize energy consumption, CO₂ purity requirements to ensure long machinery and pipeline lifetimes, and availability of the fluid property data needed for the expected CO₂/impurity mixes to enable equipment suppliers to develop optimum designs for compressors, piping, valves, and other components.

CO₂ Storage

- "Technology Watch: CO₂ Storage" highlights developments and trends in carbon capture through periodic updates on worldwide CO₂ storage research. It is integrated with the "Technology Watch: CO₂ Capture."
- Assessments of CO₂ disposal, storage, and utilization issues examine the range of potential environmental or geological impacts that could occur due to large-scale, long-term CO₂ injection into underground formations. Such impacts include potential migration of CO₂ into underground sources of drinking water (USDW), induced seismicity, leakage through fissures or faults, and well integrity.
- CO₂ purity requirements for storage assesses the potential geochemical reactions between different levels of pollutants (especially SO_x) in the CO₂ stream and the formation structure into which the CO₂ is being injected. Research will consider the plugging and consequent reduction in injectivity and capacity that could be caused by such reactions. It will also investigate the potential for any hazardous constituents in the CO₂ to migrate from the injection formation into USDWs with or without accompanying CO₂ migration.

Accomplishments

EPRI is recognized as a key source of technically sound, unbiased information on emerging CO₂ capture process (including post-combustion processes) as well as the feasibility and issues associated with CO₂ transport and geo-storage. Recent R&D highlights include:

- Identifying and providing early development support for a promising new post-combustion CO₂ capture technology, the chilled ammonia process.
- Creating a partnership with a worldwide, exclusive chilled ammonia process commercializer to further develop the process on a large pilot slipstream, obtaining a host site, creating a collaborative of more than 35 partners, directing the development testing program, and managing the subsequent economic analysis. Results from this project are providing guidance to the next, 10x-scaled-up validation test.
- Identifying and assessing compression options for CCS applications, including new, less energy-intensive compressor designs.
- Identifying and evaluating the technical feasibility of more than 50 novel CO₂ capture processes under development, narrowing the candidate processes to fewer than 20.
- Informing members about CCS developments worldwide through participation in several international networks of specialists.
- Documenting the process of finding, validating, and permitting injection sites through a management role in two DOE Regional Carbon Sequestration Partnerships and a supporting role in a third.
- Developing health risk profiles on humans and animals of economic importance for use in risk assessments.

Current Year Activities

Program R&D for 2010 will focus on completing efforts already under way, aggressively seeking new capture process ideas from universities and individual developers, expanding research on the potential environmental impacts of geo-storage, beginning to address the question of CO₂ purity requirements for long-lasting compressors and favorable/safe injection reservoir conditions, and considering options for minimizing energy penalties through optimized thermal integration of the CO₂ capture and compression process with the host power plant. Expected products include:

- Findings of new technologies, scientific concepts with promise of significant improvements of CO₂ capture, experience in CCS, and other benefits through participation in worldwide networks and conferences
- Technical and economic assessments of new or improved emerging post-combustion CO₂ capture processes, including select process simulations
- Progress reports on several promising sorbent-based capture processes—including capture effectiveness and cost, as well as engineering designs to transport the large solid masses effectively—via development accelerated by EPRI support
- Information about potential impacts on drinking water aquifers if contacted by CO₂ seeping from injection zones
- Preliminary results from expanding focus group education to wider audiences in search of communication tools that promote regional public acceptance of CCS
- Methodology for selecting CO₂ transport and storage arrangements based on business factors
- Update on compressor options with reduced parasitic load
- Preliminary assessments of impacts on potable water if injected CO₂ migrates into underground sources of drinking water
- Initial analyses of methods to avert induced seismicity due to CO₂ injection
- Status update on the effectiveness of measurement, monitoring, and verification (MMV) techniques to verify CO₂ permanence and traceability.

Estimated 2010 Program Funding

\$4.2M

Program Manager

Richard Rhudy, 650-855-2421, rrhudy@epri.com

Summary of Projects

PS165A Post-Combustion CO₂ Removal (069170)

Project Set Description

This Project Set seeks, evaluates, and demonstrates post-combustion CO₂ capture processes that are either significantly less energy-consuming and costly than technologies used in industrial applications to date or can effectively capture and store or use CO₂ in a solid form. It also assesses lower-energy-use compressors and determines purity requirements for the CO₂ stream to avoid early degradation of compressor and pipeline materials.

| Project Number | Project Title | Description |
|----------------|---|---|
| P165.001 | Technology Watch: CO ₂ Capture | By engaging with other major CO ₂ capture research organizations, EPRI provides members with up-to-date information on activities, advances, and findings worldwide. |
| P165.002 | Assessment of "Add-on" CO ₂ Capture or Fixation Systems for Combustion-Based Fossil Power Plants | This project investigates post-combustion CO ₂ capture processes that are significantly less costly, produce a solid capable of being landfilled, or that minimize water consumption and possible contamination. |
| P165.003 | CO ₂ Compression Technology and Transportation Systems | This project supports development of materials, systems, and processes needed to compress and transport captured CO ₂ to storage and use sites. |

P165.001 Technology Watch: CO₂ Capture (069171)

Key Research Question

Post-combustion CCS from any power generation source poses very complex and costly challenges with substantial uncertainty. RD&D to find economically and environmentally acceptable solutions is expensive, but because the impact of CO₂ emissions on global climate is of concern to many nations and nongovernmental organizations, researchers worldwide are seeking solutions. To maximize the value of their RD&D investment, avoid unnecessary duplication, and benefit from the world's best expertise, members need access to this research.

Approach

EPRI provides a link to the worldwide CCS RD&D community through its participation in the IEA Greenhouse Gas Program and MIT Carbon Sequestration Initiative, as well as its attendance at numerous conferences and workshops. EPRI provides a newsletter that summarizes the latest findings and R&D directions on post-combustion CO₂ capture reported at these venues. EPRI also informs the research community about power generators' operability issues, helping guide their research.

Impact

This project serves as a central information source on worldwide activities and trends in post-combustion CO₂ capture.

- Basis for credible asset planning through early understanding of the options, development timelines, costs, uncertainties, and regulatory issues.
- Dialog about the practical extent and timing of reducing CO₂ emissions from U.S. power plants.

How to Apply Results

Environmental compliance specialists and strategic planners can stay abreast of the latest issues and progress in post-combustion CO₂ capture through advisor meetings, webcasts, newsletters, and contact with EPRI staff. They can use this information to support planning exercises and communications with policymakers, shareholders, the media, and the public.

2010 Products

| Product Title & Description | Planned Completion Date | Product Type |
|--|-------------------------|------------------|
| Newsletters on Developments in Post-Combustion CO₂ Capture | 12/31/10 | Technical Update |

Future Year Products

| Product Title & Description | Planned Completion Date | Product Type |
|--|-------------------------|--------------------|
| Issue Evaluation Report(s): Annual, topical reports on related issues that may arise during each year. | 12/31/12 | Technical Update |
| Newsletters on Developments in Post-combustion CO₂ Capture: Ongoing activity, with newsletters issued two to four times per year as determined by the availability of significant new information. End date may be sooner or later, depending on continued member interest. | 12/31/15 | Technical Resource |

P165.002 Assessment of "Add-on" CO₂ Capture or Fixation Systems for Combustion-Based Fossil Power Plants (062057)

Key Research Question

Commercial post-combustion CO₂ capture technologies used in non-power applications impose a severe energy penalty on the power plant (up to 30% of plant output) and are very complex, resulting in high capital costs and large space requirements. Processes under development (e.g., ammonia-based, advanced amines, solid sorbents, membranes) might require much less plant energy, but it is still too early to guarantee their success. Nor are they expected to achieve the ultimate goal of 10% parasitic load (excluding compression) and less than 20% increase in cost of electricity (COE). Therefore, efforts to find and demonstrate processes that could substantially lower cost and energy penalty must continue. At the same time, the industry needs options that fix CO₂ via biological or chemical means as alternatives for cases where geo-storage is not allowed or impractical. In either case, related needs include minimizing water consumption and ensuring that solvent or sorbent residues or degradation products are not released into the environment. In addition, the power industry must be able to procure and operate the most viable of these systems in time to meet regulatory requirements.

Approach

EPRI is participating in the development of several alternatives to current amine-based CO₂ capture processes, including:

- A membrane incorporated into a novel system design
- Three different solid sorbent efforts (carbonate, organic carbon-based, and a broader effort to seek and test novel sorbents along with developing a modern material handling systems for the large sorbent volumes that will be required for CO₂ capture)
- A solvent that uses phase separation to reduce regeneration energy requirements.

The expertise developed by EPRI under this project also informs the 20- to 25-MW chilled ammonia and advanced amine EPRI Industry Technology Demonstrations at AEP and Southern Company, respectively, with feedback provided to Program 165 members.

EPRI will continue to seek and evaluate novel technologies, supporting any that appear to offer significant advantages such as lower parasitic load, lower cost, or the production of a solid product to avoid the uncertainties of geosequestration. Water consumption will be one of the evaluation criteria, with a search for zero- or near-zero water consumption processes a growing priority. This support may consist of seed funding or co-funding, proof-of-concept tests, process simulations to help inventors move their invention from concept to practical system, or detailed process analyses aimed at improving a process's predicted performance. As new processes are found and information on them becomes available, EPRI will post them on the program's website in a database with downloading and searching flexibility. If promising new early-stage processes are found, EPRI will conduct proof-of-concept tests.

Impact

Participants in this project get ongoing, updated information on the progress of the project as it seeks, evaluates, and demonstrates post-combustion CO₂ capture processes that can deliver one or more of the following benefits:

- Reducing COE increase due to post-combustion carbon capture from the current estimate of 60–80% down to 20% or less.
- Reducing parasitic energy demand from approximately 30% to 10% (excluding compression).
- Capturing and storing CO₂ as a solid.

How to Apply Results

Environmental compliance specialists and strategic planners can stay abreast of the latest progress in CO₂ capture technologies by attending advisory meetings, participating in webcasts, and viewing and searching the web-based technology review. They can also follow up with EPRI staff. Members can use this information, backed by first-hand knowledge of promising developments, to support planning and communicate with policymakers, shareholders, the media, and the public.

2010 Products

| Product Title & Description | Planned Completion Date | Product Type |
|--|-------------------------|--------------------|
| <p>Assessment of CO₂ Capture Options Currently Under Development: Web-hosted database compilation of all known CO₂ capture processes with descriptions, developers, status, actual or expected performance and cost, and assessment of feasibility and performance/cost projections. Updated quarterly if merited by new information.</p> | 12/31/10 | Technical Resource |
| <p>Advanced CO₂ Capture Processes -- Feasibility of Technologies X, Y: Status reports on processes being developed with partial EPRI funding, including carbon-based sorbents, novel sorbent search and material handling systems, and MTR membrane. In addition, reports could potentially address phase separation solvents, enzyme-promoted solvents, mineralization approaches (cement production, disposable carbonates), or others to be determined.</p> | 12/31/10 | Technical Update |

| Product Title & Description | Planned Completion Date | Product Type |
|--|-------------------------|------------------|
| Biofixation as a Post-combustion CO₂ Capture Option -- Power Plant Integration: Technical potential and integration options for removing CO ₂ from flue gas by converting it biologically to a solid, fuel, or combination. Includes techno-economic study of photobioreactors as alternatives to open ponds, with information on ponds coming from participation in ongoing member demonstrations. | 12/31/10 | Technical Update |
| Environmental Releases from Post-combustion CO₂ Capture Processes: A white paper on air emissions, liquid discharges, and solid products created by and emanating from post-combustion CO ₂ capture processes, such as solvent slip in the flue gas or concentrated CO ₂ product stream, partial decomposition products from solvents, and others. Based on survey of available information and engineering judgment on potential releases, as well as the ability to control them, it identifies next steps, such as measurement campaigns. | 12/31/10 | Technical Update |
| Accelerated Development of Promising Post-combustion CO₂ Capture Processes: Report on the construction and start-up of pilot test bays at Southern Company's Plant Gaston for demonstrating promising technologies at the intermediate scale between laboratory proof of concept and 20-plus-MW field pilot. Includes selection of technologies to be tested in 2011 and 2012, with rationale for selection and overview of test plan. | 12/31/10 | Technical Update |
| Design-to-Properties: Theoretical Analysis of Ideal Solvent, Sorbent, and Membrane Properties: Process simulation trials to identify "ideal" solvents, sorbents, and membranes, with goal of challenging chemists to develop materials with such properties. | 12/31/10 | Technical Update |

Future Year Products

| Product Title & Description | Planned Completion Date | Product Type |
|--|-------------------------|------------------|
| Accelerated Development of Promising Post-combustion CO₂ Capture Processes: Annual update on testing of emerging post-combustion CO ₂ capture technologies at Southern Company's Plant Gaston test facility. | 12/31/11 | Technical Update |
| Accelerated Development of Promising Post-combustion CO₂ Capture Processes: Annual update on testing of emerging post-combustion CO ₂ capture technologies at Southern Company's Plant Gaston test facility. | 12/31/12 | Technical Update |
| Demonstration Tests of Advanced CO₂ Capture Processes – Annual Updates: Final report in series of annual reports on test results from large-pilot CO ₂ capture processes. Continued pilot testing beyond 2013 to be decided by members and availability of processes meeting program cost and energy penalty goals. | 12/31/13 | Technical Report |
| Proof-of-Concept Tests of Advanced CO₂ Capture Processes – Annual Updates: Final report in series of annual reports on proof-of-concept tests of advanced, potential breakthrough CO ₂ capture processes. Continued testing beyond 2013 to be decided by members and availability of processes meeting program cost and energy penalty goals. | 12/31/13 | Technical Report |
| Proof-of-Concept Tests of CO₂ Ideal Separation Media: Laboratory and pilot tests of designer solvents, sorbents, or membranes based on design-to-properties results. | 12/31/13 | Technical Report |

| Product Title & Description | Planned Completion Date | Product Type |
|--|-------------------------|------------------|
| Accelerated Development of Promising Post-combustion CO₂ Capture Processes: Final report in series of annual test reports of emerging technologies at Southern Company's Plant Gaston post-combustion CO ₂ capture test facility. | 12/31/13 | Technical Report |

P165.003 CO₂ Compression Technology and Transportation Systems (069172)

Key Research Question

Scale, energy requirements, and materials compatibility with CO₂ streams are significant challenges facing the industry and its equipment and service suppliers involved in compressing and transporting captured CO₂ to storage or use sites. Both flow volumes and energy requirements will be much greater than current practice. Cleaning the CO₂ stream produced by the capture system to very high purity levels will be expensive, so it is important to determine the impact of impurities on the flow properties that affect the design of compressors, intercoolers/heat exchangers, and valves, as well as the tolerance of a range of possible compressor and pipeline materials to different levels of impurities.

Finally, wide deployment of CCS most likely will lead to a complex network of pipelines that provide a dynamic connection between CO₂ sources, with constantly varying CO₂ flow rates (as the host plants follow load), and end uses or storage sites, with their own response to changing injection flows.

Approach

EPRI will conduct multi-faceted research over a number of years, in collaboration with DOE, other federal agencies, compressor manufacturers, and pipeline operators. Initial efforts are focusing on obtaining data on the trace impurities that may remain with captured CO₂ from the various CO₂ capture pilot tests and demonstrations. Based on these data and current CO₂ pipeline experience, EPRI will study the corrosion of carbon steels by supercritical CO₂ with varying impurity types and concentrations, consider the durability of seals and gaskets to such fluids, and ensure that thermodynamic and flow property data are available for compressor, valve, and pipeline designers. EPRI will monitor actions by pipeline owners/operators to develop systems that allow CO₂ to flow from a number of sources to the ultimate storage site. Joint efforts with Program 66 CoalFleet for Tomorrow® in 2011 and beyond will seek methods to minimize compressor energy demand on the power plant and various methods of integrating the thermal energy flows between the compressor, CO₂ capture system and power plant, or by using the optimum energy source for the compressor drive.

Impact

- Compression is estimated to account for one-third to one-fourth of the total energy demand of a CCS system on a power plant, corresponding to an approximate 6% reduction in the plant's net (salable) output. The planned research could reduce this energy drain to 3–4%.
- Transport costs may be as high as \$5–10/ton CO₂ (amortized capital plus O&M). Reducing those costs by just \$1/ton through, for example, longer lifetime pipelines, would save a 500-MW plant \$2.5 million/yr, if passed through to the power plant by the pipeline operator.

How to Apply Results

Power company system engineers can use project findings on purity requirements to design or specify capture technologies that provide a CO₂ stream of the required purity for feeding into a commercial pipeline. For power plants with a dedicated transport line to a storage site, system engineers can conduct trade-off analyses between higher-purity CO₂ and higher-grade materials. Power plant engineers can use information on possible thermal integration of the compressor with the power plant or the CO₂ capture system to place the least energy demand on the power plant.

2010 Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|-------------------------|-----------------------------------|
| Workshop on CO₂ Compression and Storage: Follow-on to a 2009 workshop, with discussion of pipeline and compressor materials, CO ₂ purity specifications, CO ₂ thermodynamic properties and equations of state, and infrastructure design (business and technical) for an eventual CO ₂ pipeline network linking multiple plants and end use or storage sites. | 08/31/10 | Workshop, Training, or Conference |
| Assessment of Materials Needs for Pipelines Transporting Power Plant-Derived CO₂: Information on constituents of CO ₂ discharged by operating CO ₂ capture pilots. Includes condition assessment of existing pipelines and projection of potential differences when transporting power plant CO ₂ with various levels of impurities, definition of R&D needed to determine material requirements for handling the expected CO ₂ purities, and preliminary estimate of the cost trade-off between producing purer CO ₂ and using more expensive materials in compressors and pipelines. | 12/31/10 | Technical Update |

Future Year Products

| Product Title & Description | Planned Completion Date | Product Type |
|--|-------------------------|-----------------------------------|
| Advances in CO₂ Compressor Technology and System Design -- Interim report: Interim assessment of state-of-the-technology CO ₂ compressors specifically designed for the large volumes, high pressure ratios, and unique fluid properties of power plant CO ₂ up to supercritical conditions. Provides conceptual designs for thermal integration of the compressor and the power plant or CO ₂ capture regeneration process step to minimize overall energy demand of the capture and compression system. | 12/31/11 | Technical Update |
| Workshop on CO₂ Compression and Storage: Follow-on to the August 2010 workshop, with discussion of pipeline and compressor materials, CO ₂ purity specifications, and infrastructure design (business and technical) for an eventual CO ₂ pipeline network linking multiple plants and end use or storage sites. | 08/31/12 | Workshop, Training, or Conference |
| Economics of CO₂ Purity Specifications: Cost trade-off analysis between producing higher purity CO ₂ streams and using more corrosion-tolerant alloys for pipelines, based on corrosion studies of varying impurity streams and pipeline alloys. | 12/31/12 | Technical Report |
| Advances in CO₂ Compressor Technology and System Design: Assessment of state-of-the-technology CO ₂ compressors specifically designed for the large volumes, high pressure ratios, and unique fluid properties of power plant CO ₂ up to supercritical conditions. It includes conceptual designs for thermal integration of the compressor and the power plant or CO ₂ capture regeneration process step to minimize overall energy demand of the capture and compression system. | 12/31/12 | Technical Report |

PS165B CO₂ Storage (069173)

Project Set Description

By studying CO₂ behavior once it is injected underground, this Project Set will advance the acceptability of CCS or identify issues to be addressed to reach that goal. R&D efforts include participation in DOE Regional Partnership projects, experimental field studies on the impact on drinking water if CO₂ seeps from the target injection formation and reaches an underground potable aquifer, experimental or monitoring studies of brine displacement by CO₂ (especially in closed reservoirs), and methods to ensure the integrity of caprock.

| Project Number | Project Title | Description |
|----------------|--|--|
| P165.004 | Technology Watch: CO ₂ Storage | By engaging with other major CO ₂ storage research organizations, EPRI provides members with up-to-date information on activities, advances, and findings worldwide. |
| P165.005 | CO ₂ Disposal/Storage and Utilization Issues Assessment | EPRI will help develop the information needed to demonstrate that injection and storage of CO ₂ into underground formations can be permanent, environmentally acceptable, and safe. |
| P165.006 | CO ₂ Purity Requirements for Storage | This project will determine purity requirements for CO ₂ streams produced by the CO ₂ capture process that avoids plugging of the target injection formation and minimizes potential risk to any nearby USDWs. |

P165.004 Technology Watch: CO₂ Storage (069174)

Key Research Question

CO₂ storage from power generation poses very complex and costly challenges with substantial uncertainty. RD&D to find economically and environmentally acceptable solutions is expensive, but because the impact of CO₂ emissions on global climate is of concern to many nations and nongovernmental organizations, researchers worldwide are seeking solutions. To maximize the value of their RD&D investment, avoid unnecessary duplication, and benefit from the world's best expertise, power companies need access to this research.

Approach

EPRI provides a link to the worldwide CO₂ storage RD&D community through its participation in the IEA Greenhouse Gas Program and MIT Carbon Sequestration Initiative, as well as by attending numerous conferences and workshops. Periodically, EPRI prepares a newsletter that summarizes the latest CO₂ storage findings and R&D directions. EPRI also informs the research community of power generators' concerns about the magnitude of their CO₂ production and need to understand the risks to storage formation injectivity and capacity, as well as to underground sources of drinking water, posed by impurities in the CO₂ stream.

Impact

This project serves as a central information source on worldwide activities and trends in CO₂ storage from any power generation source. EPRI work in this project:

- Supports asset planning through early understanding of the options, development timelines, costs, uncertainties, and regulatory issues involved in CO₂ storage
- Provides information about the practical extent and timing of CO₂ reduction from U.S. power plants.

How to Apply Results

Environmental compliance specialists and strategic planners can stay abreast of the latest issues and progress in CCS through meetings, webcasts, newsletters, and contact with EPRI staff. They can use this information in planning and communications with policymakers, shareholders, the media, and the public.

2010 Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|-------------------------|------------------|
| Newsletters on Developments in CO₂ Storage: Periodic reports on technical advances, issues, policy changes, and related issues as heard and observed in meetings attended by EPRI staff, or as received in newsletters and reports provided by the organizations to which EPRI belongs or can access. | 12/31/10 | Technical Update |

Future Year Products

| Product Title & Description | Planned Completion Date | Product Type |
|--|-------------------------|--------------------|
| Issue Evaluation Report(s): Topical reports on CO ₂ storage issues, as identified and not covered elsewhere. | 12/31/12 | Technical Update |
| Newsletters on Developments in CCS: Ongoing activity, with newsletters issued two to four times per year as determined by the availability of significant new information. End date may be sooner or later, depending on continued member interest. | 12/31/15 | Technical Resource |

P165.005 CO₂ Disposal/Storage and Utilization Issues Assessment (052326)

Key Research Question

Although as much as 80% of the cost of CCS is attributable to the capture process, most of the uncertainties surround the means of permanently storing CO₂. The industry and public need confidence in the ability to safely inject and store CO₂ in underground formations with greater than 99% permanence over very long periods and with no undesirable side effects. Socio-political issues include legal or regulatory procedures for dealing with long-term liability for injected CO₂, the potential health and environmental effects of leaks, and permitting.

R&D needed to resolve those issues includes demonstrating the ability to monitor the fate and movement of injected CO₂ in underground formations to ensure its permanence in the target storage formation and absence of intrusion into potable groundwater reservoirs. Research will also assess how to mitigate any CO₂ impact on public health, environment, and natural resources (groundwater), as well as the purity requirements for long-lasting, effective CO₂ injection.

Approach

EPRI-planned and managed studies, in collaboration with AEP and its Mountaineer capture and storage project, in addition to participation in several DOE Regional Carbon Sequestration Partnerships, are addressing the need to prove the effectiveness and safety of geostorage. These efforts include:

- Experimental and modeling investigations in 2010 to address questions about the potential for injected CO₂ to contact and affect aquifers containing potable groundwater
- Scoping studies and development of remediation techniques in case of over-pressurization or CO₂ release from the intended storage formation

- Guidelines for successful permitting
- Prediction of injectivity and storage capacity by pre-injection and surface-based measurement techniques
- Post-injection measurement, monitoring, and verification approaches suited for CO₂ underground flow management using surface measurements
- Models that correctly simulate CO₂-formation geochemistry, the CO₂ plume, possible leakage pathways, and related issues.

EPRI also will begin to create a national site-screening database, starting with guidelines for site selection. Studies on allowable impurities in the CO₂ stream to avoid deterioration of the injection formation are addressed in Project P165.006.

Impact

The project will advance the acceptability of CCS or identify issues that must be addressed to reach this goal. The project will help:

- Increase the probability that CO₂ underground storage will be available (i.e., that industry and regulators will have the necessary experience and tools to engineer and permit such projects) and accepted when needed (e.g., 2020 or sooner).
- Provide credible information that can be used by project applicants and policymakers or permit writers to develop workable and scientifically based regulations and legal frameworks for underground CO₂ storage, guidelines on characterizing a formation before injection to satisfy permit writers and risk managers, and technologies to monitor the underground migration of injected CO₂. Achievement of these goals before power companies need to apply for permits will save applicants several years and up to millions of dollars in permitting costs at each of the first several sites.
- Avoid the need to purchase allowances by being able to show permitting authorities that proposed geostorage is permanent and safe. At a conservatively low allowance price of \$20/ton CO₂, this could save a 2,000-MW plant \$500 million in purchased allowances over five years if the absence of adequate information prevents the company from receiving an injection permit.

How to Apply Results

Power company personnel at all levels (planning, asset management, environmental engineering, environmental policy, risk management, legal) and management can use the results of this project to assess their options and guide the implementation of their strategies.

2010 Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|-------------------------|------------------|
| Potential Impact of Injected CO₂ on Drinking Water Aquifers: Results of field tests of changes in water chemistry after injected CO ₂ migrates through underground formations and reaches a water reservoir, including metals and organics that may be mobilized out of the formation rock. Due to the high cost of deep wells, tests will be at depths of approximately 100 feet and use suction pumps to accelerate CO ₂ migration from injection well to drinking water reservoir. | 12/31/10 | Technical Report |
| Reservoir Remediation Techniques -- Scoping Study: Assessment of RD&D needs based on literature review and discussions with scientists and engineers engaged in large-volume injection programs that have planned or implemented remediation measures. | 12/31/10 | Technical Update |

| Product Title & Description | Planned Completion Date | Product Type |
|--|-------------------------|------------------|
| Assessment of Sequestration Options: Summary of 2009-2010 experiences with CO ₂ geostorage (primarily in DOE Regional Partnerships) and resulting findings. Results will focus on lessons learned, assessment of the ability to predict and monitor CO ₂ migration underground, and guidance on engaging the public and regulators. They will also review issues relating to brine displacement due to CO ₂ injection, next steps to determine the impact of brine displacement, if any, and possible mitigation strategies (e.g., pressure management) for both closed and open reservoirs. | 12/31/10 | Technical Update |

Future Year Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|-------------------------|------------------|
| Guidelines for Site Selection and Permit Applications – 1st Update: Update of 2010 assessments of sequestration options based on DOE Phase 3 and private-sector demonstrations, plus supporting technical studies (e.g., CO ₂ /potable water interactions and caprock integrity) and anticipated EPA regulations for injection (under the Underground Injection Control (UIC) program). | 09/30/11 | Technical Report |
| Guidelines for Site Selection and Permit Applications – 2nd Update: Update on 2011 assessment of sequestration options based on two more years of injection and monitoring at DOE Phase 3 and private-sector demonstrations, plus supporting technical studies (e.g., further definition of drinking water concerns, caprock integrity, mobilization of metals and organics) and findings on legal and liability issues. | 12/31/13 | Technical Report |

P165.006 CO₂ Purity Requirements for Storage (069175)

Key Research Question

Very little or no data are publicly available on potential fluid/formation interactions when the injected fluid is supercritical CO₂ derived from a coal power plant, but such information is needed to understand the purity requirements of a CO₂ stream to be injected into particular types of underground formations. Injected fluids can react with the formation water to produce precipitates, mineral dissolution or biofouling, which can result in formation plugging, well integrity problems, or well failure. Further, constituents in the CO₂ may have different mobilities than the CO₂ itself (e.g., they may partition into the receiving brine or stay with the CO₂ plume) and these constituents may present an environmental or health risk if they reach an underground source of drinking water.

Approach

EPRI will conduct a multi-year research and information exchange program to determine how pure a CO₂ stream must be when delivered to an injection formation. The objective is to understand the purity that enables a target injection formation to realize its maximum injectivity and capacity, while avoiding potential exposure of USDWs to hazardous constituents that might be in the CO₂ stream. This project will be coordinated with related work in P165.003 that considers CO₂ purity requirements to maintain the integrity of the compression and transport systems. Initial efforts to obtain data from various CO₂ capture pilot tests and demonstrations on the trace impurities that may remain with the captured CO₂ will serve both projects. EPRI will:

- Identify impurities and compile available concentration data, thermodynamic properties, solubilities and reactive transport coefficients (if available) from the literature, pilot plants, and measurement data it can

obtain from other pilot plants worldwide (e.g., from other IEA participants) or from analogs (e.g., natural gas CO₂ separation plants). These data will be collected for use in multiphase (groundwater and CO₂) reactive transport flow models.

- Perform flow and transport simulations on major rock types (such as mock sandstone, cemented sandstone, dolomites, and limestone) with typical mineral compositions and for various levels of potential impurities in the CO₂ stream. The simulations will determine the vulnerability of these formations to precipitation, biofouling, and contaminant migration out of the target formation with any escaping CO₂ or displaced brine. EPRI also may conduct CO₂ core floods in the laboratory to calibrate and validate the transport models.
- Obtain toxicity data on any potentially hazardous constituents and perform risk assessments using the flow and transport models (or risk-based models) to determine if these constituents, at different potential concentrations in the CO₂ stream, will exceed health risk standards if leaked into a USDW.

Impact

By providing guidance on the purity requirements for storage, this project will enable members to avoid the:

- Costs of CO₂ stream clean-up to unnecessarily stringent levels
- Risk and cost of having to drill additional injection wells, retrofit additional equipment to the CO₂ capture plant to further clean up the CO₂ stream, or even move to a different location because constituents in the CO₂ caused plugging of an injection formation
- Risk and cost of having to remediate a USDW that has been contaminated by a hazardous species that migrated from the injection formation to the USDW.

How to Apply Results

Power company reservoir engineers and CO₂ capture process design engineers can use the tools and information developed by this project to make decisions on the purity requirements needed for the storage formations under consideration and support underground injection permitting, specifically with regard to potential risks to any USDWs above the target injection formation.

2010 Products

| Product Title & Description | Planned Completion Date | Product Type |
|--|-------------------------|------------------|
| Preliminary Assessment of Impurities in CO₂ Streams from Coal Power Plants: Initial data on impurities in CO ₂ streams from post-combustion CO ₂ capture pilot plants (laboratory and field scale, as available). Plans to obtain data needed for reactive chemistry transport models. | 12/31/10 | Technical Update |

Future Year Products

| Product Title & Description | Planned Completion Date | Product Type |
|---|-------------------------|------------------|
| Assessment of Impurities in CO₂ Streams from Coal Power Plants: Compilation and analysis of data on impurities in CO ₂ streams from post-combustion CO ₂ capture pilot plants (laboratory and field scale). Identification of any hazardous pollutants in these CO ₂ streams. Summary of available thermodynamic, solubility, and reactive transport coefficient data. | 12/31/11 | Technical Report |
| Initial Flow and Transport Simulation: Results of first simulation (one formation type) with prediction of potential for plugging by precipitation or biofouling, or of a risk to a USDW due to impurities in the CO ₂ . Recommendations on need for further development of models and geochemistry rate data. | 12/31/12 | Technical Update |

| Product Title & Description | Planned Completion Date | Product Type |
|---|-------------------------|------------------|
| Flow and Transport Simulation – Formation Type X: Results of simulation on either same or different formation than initial simulation, using enhanced model (per recommendations in 2011 report). Possible data validation from field tests (e.g., DOE Regional Carbon Sequestration Partnerships, AEP Mountaineer chilled ammonia plus injection into two reservoirs, or others.) | 12/31/13 | Technical Update |
| Flow and Transport Simulations – Additional Formations: Results of simulations on the remaining selected formation types (e.g., per list in the Approach discussion). Initial assessment of CO ₂ purity requirements for different types of formations, based on potential for formation plugging. | 12/31/14 | Technical Report |
| CO₂ Purity Requirements for Storage: Recommended CO ₂ purity requirements for different formations, overlying geologies, and potential leakage into USDWs, based on both pluggage and risk assessment of potential health impacts on potable aquifers. | 12/31/15 | Technical Report |