CO_2 Capture and Storage - Program 165

Program Overview

Program Description

Policy watchers and power system planners increasingly are predicting that post-combustion capture will be needed in the 2020 decade for both existing and new coal-fired plants, and somewhat later for gas-fired systems, in order to meet carbon dioxide (CO_2) reduction targets being discussed in the United States, by many other governments, and within the United Nations. An associated need for all fossil-fueled electricity generation sources is permanent and environmentally safe storage of the captured CO_2. For pulverized coal (PC) plants to provide competitively priced electricity while addressing these CO_2 reduction concerns, they need capture processes with much lower parasitic plant loads and costs than systems available today. All power generation sources of CO_2 also will need the ability to store large quantities of CO_2 safely and permanently in underground formations. While establishing the necessary legal and regulatory framework is not within the purview of EPRI, providing sound technical evidence that storage can be done in a safe and permanent fashion can support the development by others of workable regulations and enabling laws.

EPRI's CO_2 Capture and Storage program (Program 165) provides information about the expected cost, availability, performance, and technical challenges of a range of flue gas CO_2 capture processes. The program seeks and encourages the development of breakthrough post-combustion CO_2 capture technologies with substantially lower energy and cost penalties. In addition, the program determines purity requirements for the CO_2 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 CO_2 storage from any power plant source.

Research Value

Substantial barriers must be overcome, and technical and societal uncertainties must be resolved before carbon capture and storage (CCS) can be widely deployed, but time is growing short if a 2020 date for federal CO_2 limits materializes. Proposed PC plants already have been denied permits in the absence of firm plans to capture and store their CO_2 emissions. This program meets the industry's most urgent near-term needs—information for:

- Credible asset planning through early understanding of the options, development timelines, costs, technical uncertainties, and regulatory, environmental, 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 CO_2 reduction from U.S. power plants, using neutral third-party data and assessments from EPRI.

Longer-term, the technology development aspects of this program will enable the power sector to continue to provide affordable electricity to industry, businesses, and residences using fossil-fuel-fired generating assets in a low-carbon world.

Approach

This program pursues parallel, complementary activities in post-combustion CO_2 capture and in storage of CO_2 from any fossil-fueled electricity generation source. For post-combustion capture, EPRI will continue to seek potential breakthrough technologies that offer the promise of significant cost and energy demand reductions over today's leading candidates. EPRI then will conduct technical and economic assessments of these processes, followed by development and demonstration of the most promising ones, in order to accelerate the availability of commercially mature, cost-acceptable carbon capture methods. Based on offers to collaborate with developers of a number of interesting CO_2 capture process developers in their bids to the U.S. Department

of Energy (DOE), EPRI may engage in 5 to 10 such activities in 2011 and beyond. For CO_2 storage, EPRI will conduct or participate in multiple, large, multiyear CO_2 geologic storage projects designed to provide the information and tools needed to gain public and regulatory acceptance of commercial-scale CO_2 storage. Topical studies (e.g., predicting and countering any environmental impacts of contact between injected CO_2 and potable aquifers) will address other underlying geochemical processes that affect formation and well integrity not tested in the demonstrations. Members receive this information through two project sets with three projects each:

Post-combustion CO_2 Removal

- "Technology Watch: CO_2 Capture" highlights developments and trends in carbon capture through periodic updates on worldwide post-combustion CO_2 capture research. Information is obtained through participation in various international forums, workshops, and conferences.
- Assessments of “add-on” CO_2 capture or fixation systems for new and retrofit combustion-based fossil power plants continue to be collected in a database of CO_2 capture processes, with in-depth assessments where appropriate. Increasingly, EPRI’s R&D is focusing on collaborations with process developers across the spectrum of technologies to accelerate the development of their concepts. In support of both the assessment and development efforts, EPRI conducts process simulations for further improvements through optimized design and thermal integration with the power plant. Complementing these development efforts, the program continues to co-produce economic studies of diverse post-combustion CO_2 capture technologies and energy integration schemes with the CoalFleet for Tomorrow® Program (EPRI Program 66).
- R&D involving CO_2 compression technology and transportation systems focuses on the purity of the capture system’s CO_2 product stream needed to ensure long compressor and pipeline lifetimes; the fluid properties of the expected CO_2/impurity mixes needed to develop optimum designs for compressors, piping, valves, and other components; and the ability of the compression system to remove species that could be detrimental to the downstream transport pipelines. These studies include economic trade-offs between producing low-impurity CO_2 and protecting downstream equipment.

CO_2 Storage

- "Technology Watch: CO_2 Storage" highlights developments and trends in carbon storage through periodic updates on worldwide CO_2 storage research. It is integrated with "Technology Watch: CO_2 Capture."
- Assessments of CO_2 storage summarize experiences in large-scale storage demonstrations, seeks optimum methods and economics for evaluating potential geologic storage formations; quantifies potential environmental risks — e.g., from migration of injected CO_2 into underground sources of drinking water (USDW); considers ways to remediate potential breaches of storage integrity; and assesses the effectiveness of techniques being developed for predicting and monitoring the location of the underground CO_2 plume.
- CO_2 purity requirements for storage assess the potential geochemical reactions between different levels of impurities (especially SO_x) in the CO_2 stream and the geologic formation into which the CO_2 is being injected. Research will consider the plugging/dissolution and consequent reduction/increase in injectivity and capacity that could be caused by such reactions.

Accomplishments

EPRI is recognized as a key source of technically sound information on emerging CO_2 capture processes (including post-combustion processes), as well as the feasibility and issues associated with CO_2 transport and geo-storage. Recent R&D highlights include:

- Managing and completing the pilot-scale (1.7 MWe) testing of the chilled ammonia process, leading to its scale-up by a factor of 10 (to 20-MWe) for the Product Validation Facility program being conducted with EPRI support by American Electric Power (AEP) and Alstom at AEP’s Mountaineer station.
- Identifying and evaluating the technical feasibility of more than 100 novel CO_2/flue gas separation concepts or processes under development, narrowing the promising processes to fewer than 20. Updating earlier assessments to account for recent developments and adding new processes as

identified. Providing capsule information and assessments to members in a web-based database for program members.
- Participating in bids to DOE for further development support by approximately half the developers considered most promising by EPRI, thereby giving EPRI members a window into early development status and potential of a wide range of potential CO_2 capture processes — solvent, sorbent, membrane, and mineralization.
- Preparing a high-level overview on the potential role of algae fixation as a CO_2 capture strategy for power plants.
- Providing sorbent process developers with feedback on their test approaches, leading to more technically-solid progress towards identification of processing sorbents and sorbent-handling systems.
- Completing a scoping test on the potential for CO_2 to alter groundwater chemistry if it migrates from its injection formation into an underground source of drinking water (USDW).
- Identifying and assessing compression options for CCS applications, including new, less energy-intensive compressor designs.
- Following the above with an assessment of the opportunities and challenges of integrating post-combustion CO_2 capture, product stream purification for minimum impact on downstream components, and compression.
- 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.
- Documenting public acceptance, permitting, and legal state-of-the-issue.

Current Year Activities

Program R&D for 2011 will focus on completing efforts already under way, aggressively seeking new capture process ideas from universities and individual developers; actively supporting selected CO_2 separation process developers with system modeling and power plant insights as they advance their technologies under DOE or state funding; investigating potential emissions of solvent or sorbent slip and/or degradation products; expanding research on the potential environmental impacts of geostorage (especially potential impacts of CO_2 leakage on USDW chemistry in a more realistic environment than the 2009 scoping test); beginning to address the question of CO_2 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 CO_2 capture and compression process with the host power plant. Expected products include:

- Findings of new technologies and/or scientific concepts with the promise of significant reductions in the cost and energy requirements for CO_2 capture, and ways to ensure the permanence and environmental safety of geo-storage through participation in worldwide networks and conferences.
- Technical and economic assessments of new or improved emerging post-combustion CO_2 capture processes, including select process simulations.
- Progress reports on pilot-scale testing of processes with EPRI involvement that are selected for funding in 2010 by DOE and/or state agencies.
- Performance reports on the first post-combustion CO_2 capture processes to be tested at the National Carbon Capture Center (expected to be both solvent and sorbent processes, possibly including technologies from abroad and new entries by major US OEMs to the power industry).
- Preliminary concepts for reducing/avoiding atmospheric releases of solvent or sorbent degradation products with the flue gas (pending the finding of such releases in 2010 or early 2011).
- Update on compressor options with reduced parasitic load and/or the ability to assist in purification of the CO_2 product stream, where needed.
- Preliminary measurements of any changes in potable water quality if injected CO_2 migrates into an underground source of drinking water.
- Initial assessment of the potential impact, if any, of impurities in the CO_2 product stream on the receptivity of target geo-storage formations to receiving and storing large volumes of CO_2.
- Search for concepts for reducing the costs of qualifying geostorage formations.

- Initiation of a project to evaluate methods to remediate CO_2 leakage pathways if leakage is detected.
- Initiation of effort to survey and synthesize field experience with measurement, verification, and accounting (MVA) techniques to determine CO_2 permanence and traceability.

Estimated 2011 Program Funding

$4.5M

Program Manager

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Summary of Projects

PS165A Post-Combustion CO_2 Removal (069170)

Project Set Description

This project set seeks, evaluates, and demonstrates post-combustion CO_2 capture processes that either are significantly less energy-consuming and costly than technologies used in industrial applications to date, or can effectively capture and store or use CO_2 in a solid form. It also assesses lower-energy-use compressors and determines purity requirements for the CO_2 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/energy-demanding, produce a solid capable of being landfilled, or 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 economically compress and transport captured CO_2 to storage and use sites.

P165.001 Technology Watch: CO_2 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 CO_2 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 will continue to provide a link to the worldwide CCS RD&D community through its participation in several organizations — the International Energy Agency (IEA) Greenhouse Gas Program, Massachusetts's Institute of Technology (MIT) Carbon Sequestration Initiative, the British Biomass & Fossil Fuel Research Alliance — as well as staff attendance at numerous conferences and workshops. EPRI provides a newsletter that summarizes the latest findings and R&D directions on post-combustion CO_2 capture reported at these venues; these newsletters also include updates on CO_2 storage, as described under Project 165.004 (i.e., one newsletter for both Tech Watch activities). 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 CO_2 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 CO_2 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 CO_2 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.

2011 Products

Product Title & Description	Planned Completion Date	Product Type
Newsletters on Developments in Post-Combustion CO_2 Capture: Ongoing activity, with newsletters issued one to two times per year as determined by the availability of significant new information.	12/31/11	Technical Resource

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Newsletters on Developments in Post-Combustion CO_2 Capture: Ongoing activity, with newsletters issued one to two 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" CO_2 Capture or Fixation Systems for Combustion-Based Fossil Power Plants (062057)

Key Research Question

Commercial post-combustion CO_2 capture technologies used in nonpower applications would impose a severe energy penalty on the power plant (potentially over 30% of plant output for the capture process and compression of the concentrated CO_2 product stream to supercritical conditions) 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 still is too early to guarantee their ability to achieve energy/cost targets that would keep pulverized coal-fired electricity generation units competitive with gas-fired systems in a low-carbond environment. Therefore, efforts to find and demonstrate processes that could substantially lower costs and energy penalties must continue. At the same time, the industry needs options that fix CO_2 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. And all these challenges must be overcome rapidly so that the power industry will be able to procure and operate the most viable of these systems in time to meet regulatory requirements.

Approach

EPRI will continue to participate in the development of several post-combustion processes that hold the promise of significantly reduced energy/cost penalties, including:

- A membrane incorporated into a novel system design
- Solid sorbents (organic carbon-based, amine-impregnated, and, potentially others found during the ongoing search), along with the demonstration of a modern materialhandling systems for the large sorbent volumes that will be required for CO_2 capture
- A solvent that uses phase separation to reduce regeneration energy requirements.

Starting in mid-to-late 2010, EPRI expects to join with the DOE and potentially other government agencies to help accelerate the development of a number of additional, promising CO_2 capture processes, including ionic liquids, higher-capacity amines, catalysts for enabling the use of energy-efficient but slow-reacting solvents, and alternatives to heating for regeneration. Many of these processes will be tested at the DOE's National Carbon Capture Center, operated by the Southern Company, with this program providing a fraction of the required private sector cost-share (ensuring widespread industry input into the program). Further, 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. This outreach will include major international equipment and chemical suppliers to the power industry, some in alliances with large architect/engineering firms, that announced entries into this area in 2009-2010 and can be expected to offer pilot-scale advanced options by 2011. 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 receive ongoing, updated information on the progress of EPRI's identification, evaluation, and demonstration of new post-combustion CO_2 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 levels that are competitive with natural gas-fired electricity generation.
- Reducing parasitic energy demand from approximately 30% to less than 20% (excluding compression).
- Capturing and storing CO_2 as a solid.

Participants also will receive early indications of any releases from the capture process of its capture materials or their degradation products into the environment, and means to mitigate any such harmful releases.

How to Apply Results

Environmental compliance specialists and strategic planners can stay abreast of the latest progress in CO_2 capture technologies by attending advisory meetings, participating in webcasts, and viewing and searching the web-based technology review. They also can follow up with EPRI staff. Members can use this information, backed by firsthand knowledge of promising developments, to support planning and communicate with policymakers, shareholders, the media, and the public.

2011 Products

Product Title & Description	Planned Completion Date	Product Type
Emerging Post-Combustion CO_2 Capture Processes: Web-hosted database compilation of all known post-combustion CO_2 capture processes with descriptions, developers, status. actual or expected performance and cost, and assessment of feasibility and performance/cost projections. Update periodically, as warranted.	10/31/11	Technical Resource
Environmental Releases from Post-Combustion CO_2 Capture Processes: Measurements of solvent slip or solvent/sorbent/membrane degradation products into the environment (mainly air, but also water and solids). Depends on agreement of host sites and process developers to EPRI conducting and reporting these measurements. May be from laboratory- or pilot-scale facilities. If EPRI can obtain some measurements in 2010, this report may include a discussion of options for avoiding or controlling such releases.	12/31/11	Technical Update
Accelerated Development of Promising Post-Combustion CO_2 Capture Processes: Technical update on all emerging post-combustion CO_2 capture process developments in which EPRI is involved. Will include results for projects expected to be selected by DOE for award by mid-2010 as well as the first set of technologies tested at the DOE's National Carbon Capture Center (NCCC), operated by the Southern Company at Alabama Power's Plant Gaston. Processes will be chosen for NCCC testing on the basis of readiness to move out of the laboratory for testing on flue gas at this scale in order to accelerate their advance to a 20-plus-MW field test (at another site). The report will include the selection basis for these and the next set of processes to be tested.	12/31/11	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Accelerated Development of Promising Post-Combustion CO_2 Capture Processes: Annual update on testing of emerging post-combustion CO_2 capture technologies at NCCC and other sites. Includes tests from laboratory development efforts on early-stage technologies to 0.5-2 MWe equivalent pilots at NCCC and 20-200 MWe demonstrations (to the extent EPRI is able to participate in these large projects).	12/31/12	Technical Update
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
Accelerated Development of Promising Post-Combustion CO_2 Capture Processes: Annual update on testing of emerging post-combustion CO_2 capture technologies at NCCC and other sites. Includes tests from laboratory development efforts on early-stage technologies to 0.5-2 MWe equivalent pilots at NCCC and 20-200 MWe demonstrations (to the extent EPRI is able to participate in these large projects).	12/31/13	Technical Report
Accelerated Development of Promising Post-Combustion CO_2 Capture Processes: Annual update on testing of emerging post-combustion CO_2 capture technologies at NCCC and other sites. Includes tests from laboratory development efforts on early-stage technologies to 0.5-2 MWe equivalent pilots at NCCC and 20-200 MWe demonstrations (to the extent EPRI is able to participate in these large projects).	12/31/14	Technical Report
Proof-of-Concept Tests of CO_2 Ideal Separation Media: Follow-up laboratory and pilot tests of designer solvents, sorbents, or membranes based on design-to-properties results. Larger scale and/or new materials since 2013 report	12/31/15	Technical Report

P165.003 CO_2 Compression Technology and Transportation Systems (069172)

Key Research Question

Scale, energy requirements, and materials compatibility with potential impurities in CO_2 streams are significant challenges facing the industry and its equipment and service suppliers involved in compressing and transporting captured CO_2 to storage or use sites. Both flow volumes and energy requirements for CCS systems will be much greater than current industry practice. Cleaning the CO_2 stream produced by the capture system to very high purity levels may be expensive, so it is important to determine the impact of impurities on the 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.

Wide deployment of CCS most likely will lead to a complex network of pipelines that provide a dynamic connection between CO_2 sources, with constantly varying CO_2 flow rates (as the host plants follow load), and end uses or storage sites, with their own response to changing injection flows. Hence, a need exists for tools to design optimum systems.

Approach

EPRI will continue its multifaceted research, in collaboration with DOE, research organizations internationally, compressor manufacturers, and pipeline operators. Initial efforts are focusing on obtaining data from pilot tests and demonstrations on the trace impurities that may remain with captured CO_2, with an early focus on the higher concentration impurities, such as H_2S (from IGCC plants), O_2, and water; later work will measure or predict potential impurity levels of solvents or solvent/sorbent/membrane degradation products. Together with its

partners, EPRI will develop equations of state for the higher concentration impurities in a high pressure/temperature CO_2-dominated compressor environment; these thermodynamic state data are needed to design compressors for CCS applications, especially for configurations where the compressor (with its intercoolers) is also being used to remove impurities. Thermodynamic properties for the lower concentration species will be developed in outyears, after EPRI or others have an opportunity to measure the types and quantities of these impurities at CO_2 capture test sites. Joint efforts with Program 66 CoalFleet for Tomorrow® in 2010 and beyond will seek methods, for post-combustion applications, to minimize compressor energy demand on the power plant and various methods of integrating the thermal energy flows between the compressor, CO_2 capture system and power plant, or by using the optimum energy source for the compressor drive.

In parallel, and based on the constituent data and current CO_2 pipeline experience, EPRI will study the corrosion of carbon steels by supercritical CO_2 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 CO_2 to flow from a number of sources to one or more storage formations. This review will consider how the infrastructure could be installed and how it could accommodate both varying CO_2 feed rates into it (e.g., due to power plant load changes), as well as varying storage acceptance rates (e.g., due to varying EOR demand and/or operation of the receiving formation).

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 CO_2 (amortized capital plus O&M). Reducing those costs by just \$1/ton through, for example, longer lifetime pipelines, could 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 CO_2 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 tradeoff analyses between higher-purity CO_2 and higher-grade materials. Power plant engineers can use information on possible thermal integration of the compressor with the power plant or the CO_2 capture system to place the least energy demand on the power plant.

2011 Products

Product Title & Description	Planned Completion Date	Product Type
CO_2 Compressor Technology and Pipeline System Design for CCS Applications -- State-of-Technology Assessment: Impurities in CO_2 produced at CO_2 capture pilots. Preliminary estimates of cost tradeoff between producing purer CO_2 and using more expensive materials in compressors and pipelines. Interim assessment of state-of-the-technology for CO_2 compressors specifically designed for the large volumes, high pressure ratios, and unique fluid properties of atmospheric to supercritical pressure power plant CO_2. 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. Review of studies by others on managing dynamic pipeline systems with variable quantities of CO_2 coming from power plants (due to varying load or trips) and able to be received by the storage formations.	10/31/11	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Economics of CO_2 Purity Specifications: Cost tradeoff analysis between producing higher-purity CO_2 streams and using more corrosion-tolerant alloys for pipelines, pending availability by then of corrosion test results (lab and field) of varying impurity streams and pipeline alloys.	10/31/12	Technical Report
CO_2 Compressor Technology and Pipeline System Design for CCS Applications -- State-of-Technology Update: Update of 2011 report, plus summary of *Workshop on CO_2 Compression and Storage* (follow-on to 2009 workshop).	12/31/12	Technical Report
CO_2 Compressor Technology and Pipeline System Design for CCS Applications -- State-of-Technology Update: Final report on assessment of least-energy, least-cost compression and transport approaches, including new designs and energy integration of the compressor with the plant or capture system to minimize capital cost and energy demand. Update on the 2012 cost tradeoff study between purification of the CO_2 stream versus using expensive corrosion-resistant pipeline materials.	10/31/14	Technical Report

PS165B CO_2 Storage (069173)

Project Set Description

This Project Set will advance the acceptability of CCS by studying CO_2 behavior once it is injected underground. R&D efforts include participation in DOE Regional Partnership projects, experimental field studies on the environmental impact of CO_2 leakage from the target injection formation on potable groundwater, and economic assessments of the full CO_2 transport, injection, and monitoring set of activities for different source-sink geographic relationships and storage formation characteristics. Through its involvement with the international oil-company-organized Carbon Capture Project Phase 3 (CCP3), EPRI will study methods to ensure the integrity of wells, to assess the risks of CO_2 leakage or other potential damage when selecting a site, and improve/validate Monitoring, Verification, and Accounting (MVA) methods for monitoring CO_2 location underground.

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	Assessments of CO_2 Storage Issues	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 evaluate the effect that CO_2 impurities produced by the CO_2 capture process will have on the integrity and performance of typical storage formations and the environment, leading to development of better CO_2 purity requirements.

P165.004 Technology Watch: CO_2 Storage (069174)

Key Research Question

CO_2 storage from new 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 CO_2 emissions on global climate is of concern internationally to the public, governments, 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 CO_2 storage RD&D community through its participation in the IEA Greenhouse Gas Program, the MIT Carbon Sequestration Initiative, and others, as well as by attending numerous conferences and workshops. Periodically, EPRI summarizes the latest CO_2 storage findings and R&D directions in a newsletter published jointly with project P165.001 (and shown there as a deliverable).

Impact

This project serves as a central information source on worldwide activities and trends in CO_2 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 CO_2 storage
- Provides information about the practical extent and timing of CO_2 storage 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.

P165.005 Assessments of CO_2 Storage Issues (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 CO_2. The industry and public need confidence in the ability to safely inject and store CO_2 in underground formations over very long periods and with no undesirable side effects. The industry also needs to understand the socio-political issues associated with CO_2 storage, such as legal or regulatory procedures for dealing with long-term liability for injected CO_2, effective methods of communicating the measures being taken by the industry to mitigate risks, and successful approaches to permitting underground storage.

Of the wide range of R&D needed to resolve these issues, EPRI is focusing on those that are critical to the industry yet not being covered adequately by others, and of a scope and content such that EPRI can make an impact directly or through leveraging by participation in a consortium. These efforts are: demonstrating the ability to monitor the fate and movement of injected CO_2 in underground formations to ensure its permanence in the target storage formation and absence of intrusion into potable groundwater reservoirs; understanding the potential impact of any CO_2 leaks into such drinking water sources; and proving ways to identify and mitigate such leaks if they occur. Research will also seek lower-cost methods to assess reservoirs and develop costs for the full transport, storage, and monitoring set of activities for different source-sink locations and geologic formation properties.

Approach

Through its own studies, its participation in several DOE Regional Carbon Sequestration Partnerships, and its participation in the oil-company-led Carbon Capture Project Phase 3 (CCP3), EPRI is addressing the need to prove the effectiveness, permanence, and safety of geologic storage of CO_2. These efforts include:

- Experimental and modeling investigations to address questions about the potential for injected CO_2 to render potable groundwater undrinkable if the CO_2 and the impurities that it may contain migrate into such a drinking water source
- Investigation into remediation techniques that could be used in case of CO_2 release from the intended storage formation
- Summary of successful permitting experiences, including updates on state rules
- Workshop to seek innovative strategies for measuring and predicting reservoir-scale injectivity and capacity of potential storage formations, while minimizing exploration costs.
- Summary and synthesis of experiences assessing and selecting storage locations
- Update on economics of transport and storage for a variety of reservoir properties (especially permeability, porosity, and depth, which determine the formation's potential capacity and number/cost of wells needed)
- Summary of experiences with post-injection measurement, verification, and accounting (MVA) approaches for monitoring CO_2 underground

Studies on allowable impurities in the CO_2 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 knowledge base that will enable CO_2 underground storage (i.e., that industry and regulators will have the necessary experience and tools to engineer and permit such projects) and accepted by government bodies and the public when needed (e.g., 2020 or sooner).
- Provide independent 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 CO_2 storage, guidelines on characterizing a formation before injection to satisfy permit writers and power company risk managers, and technologies to monitor the underground migration of injected CO_2. 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 geologic storage is permanent and safe. At a conservatively low allowance price of $20/ton CO_2, 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.

2011 Products

Product Title & Description	Planned Completion Date	Product Type
CO_2 Sequestration -- Progress Report on Challenges and Resolutions: Status report and summary of findings to date from EPRI and CCP3 technical studies: CO_2/potable water interactions, CO_2/mineral interactions in the storage formation, methods of caprock characterization to ensure seal performance, measurement systems for monitoring location/movement of the injected CO_2, and framework for economic studies of transport/storage/monitoring system. Potential discussion of technology needs to satisfy EPA regulations for injection (under the Underground Injection Control [UIC] program), if promulgated by then. Also, summary of any noteworthy (and publicly releasable) findings from DOE Phase 3 and private-sector geologic storage demonstrations.	12/31/11	Technical Report

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
CO_2 Sequestration -- Progress Report on Challenges and Resolutions: Status Update: Update of 2011 status report on studies of drinking water impacts, caprock characterization, site selection characterization and risk assessment, and field MVA experiences. Also will include economics of transport/storage/monitoring for different situations and summary/synthesis of sequestration experience based on one more year of injection and monitoring at DOE Phase 3 and private-sector demonstrations. If major changes occur in the legislative, regulatory, or legal arenas affecting legal and liability issues of CCS, a summary of these changes will also be included.	10/31/12	Technical Update
CO_2 Sequestration -- Progress Report on Challenges and Resolutions: Status Update: Summary/synthesis of lessons learned at injection demonstration sites, the status of the UIC regulations, approaches being used internationally and in the U.S. states that have adopted geologic storage regulations or legislation, as well as findings from the various EPRI, DOE, and CCP3 studies included in the preceding annual reports.	10/31/13	Technical Report
Site Selection and Permit Applications -- Lessons Learned: Summary and synthesis of successful practices for obtaining drilling and injection permits. Assessment of tools available to; a) characterize potential storage formations most economically and with highest probability of a positive outcome, b) demonstrate knowledge of location of injected CO_2 including potential leaks, and c) identify and mitigate potential risks to potable groundwater (understand the risk and have plan/technologies to remediate, if needed).	12/31/15	Technical Report

P165.006 CO_2 Purity Requirements for Storage (069175)

Key Research Question

Limited data are publicly available on potential fluid/formation interactions when the injected fluid is supercritical CO_2 derived from a coal power plant, which may contain impurities, but information is needed to determine the impacts of impurities to develop credible purity requirements that should be placed on a CO_2 stream to allow successful and environmentally safe injection into 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 CO_2 may have different mobilities than the CO_2 itself (e.g., they may partition into the receiving brine or stay with the CO_2 plume), and these constituents may present an environmental or health risk if they reach an underground source of drinking water (USDW).

Approach

EPRI is engaged in a multiyear research and information exchange program to determine how pure a CO_2 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 CO_2 stream. This project will be coordinated with related work in P165.003 that considers CO_2 purity requirements to maintain the integrity of the compression and transport systems. Initial efforts to obtain data from various CO_2 capture pilot tests and demonstrations on the trace impurities that may remain with the captured CO_2 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 that can be obtained from other pilot plants worldwide. These data will be collected for use in multiphase (groundwater and CO_2) reactive transport flow models. As in P165.003, the initial focus will be on the higher concentration impurities (H_2S or SO_2, water, O_2)
- 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 CO_2 stream. The simulations will determine the vulnerability of these formations to precipitation and contaminant migration out of the target formation with any escaping CO_2 or displaced brine. EPRI also may conduct CO_2 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 CO_2 stream, will exceed health risk standards if leaked into a USDW.

EPRI plans to obtain the impurity concentration data from several larger pilot-scale CO_2 capture demonstrations in which it is involved or permitted to test, as well as from projects by others that are shared openly through such forums as the IEA CO_2 Capture Network.

Impact

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

- Costs of CO_2 stream clean-up to unnecessarily stringent levels
- Risk and cost of having to drill additional injection wells, retrofit additional equipment to the CO_2 capture plant to further clean up the CO_2 stream, or even move to a different location because constituents in the CO_2 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 CO_2 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.

2011 Products

Product Title & Description	Planned Completion Date	Product Type
CO_2 Purity Requirements for Storage -- Initial Assessment: Identification and acquisition of impurity data needed for reactive chemistry transport models (concentrations in the CO_2 stream, thermodynamic properties, solubilities, and reactive transport coefficients). Initial setup of flow and transport simulations.	12/31/11	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
Initial Flow and Transport Simulation: Results of first simulation (one formation type) with prediction of potential risk to a USDW due to impurities in the CO_2. May include consideration of plugging by precipitation if considered a potential issue due to the type and concentrations of the impurities in the CO_2. Recommendations on need for further development of models and geochemistry rate data.	12/31/12	Technical Update
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 2012 report). Possible validation from field and laboratory tests.	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 risk to USDWs or formation plugging.	12/31/14	Technical Report
CO_2 Purity Requirements for Storage: Recommended CO_2 purity requirements for different formations, overlying geologies, and potential leakage into USDWs, based on both risk assessment of potential health impacts on potable aquifers and potential for pluggage of formation pores.	12/31/15	Technical Report