Carbon Dioxide Capture and Storage: The Future for Sustainable Coal Use

Overview

Around the world, electricity largely is produced from fossil fuels, and coal often is the predominant fuel choice. ***In North America, Australia, and parts of Europe, Asia, and Africa, coal-fired power plants supply more than half of the electricity consumed. Coal has become the primary fuel for affordable and reliable electric power production because it is relatively easy to transport and use and because many countries have indigenous coal resources.***

The need to limit man-made emissions of CO_2 and other greenhouse gases (GHGs) has become a familiar topic among policymakers and the public. CO_2 capture and storage (CCS) refers to processes that separate CO_2 from fossil fuels or exhaust gases at industrial or power plants, after which CO_2 can be compressed and permanently stored in deep underground formations. Known as geologic storage or sequestration, this approach for securely storing CO_2 prevents its release into the atmosphere.

The NCC fully supports all of the current R&D efforts that the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) has been conducting since 1997. These programs include the Carbon Sequestration Leadership Forum, the Regional Carbon Sequestration Partnerships, and the overall CCS R&D program. Appropriations for the program have grown from less than $1 million in 1997 to about $120 million, with a pending budget request for $149 million. Major strides have been achieved since the inception of the program. The NCC has consistently supported these programs and they need to continue to grow in the future.

Projected Growth in Global Population and Electricity Consumption*

The world's population is predicted to grow by 36%—from 6.1 to 8.3 billion people—from 2000 to 2030. The U.S. population also is forecast to grow over this period by an estimated 80 million people, or almost 30%.*

World net electric power generation is projected to increase from 14,426 billion kWh in 2000 to 30,364 billion kWh in 2030—an increase of more than 110%.** The aggregate demand growth in emerging economy (i.e., non-OECD***) countries is forecast to be nearly as great as current world electricity use.

* http://esa.un.org/unpp/
** http://www.eia.doe.gov/oiaf/ieo/excel/figure_61data.xls
*** Organization for Economic Cooperation and Development.

The NCC also works with a number of industry groups involved in R&D of CCS technologies. Among these is the Electric Power Research Institute (EPRI), which is presently examining current and potential options for reducing GHG emissions from the electric power sector. EPRI's analyses show that the implementation of advanced coal-based power systems with CCS will be required to achieve significant GHG reductions. However, CCS technology is not yet commercially viable and requires public and private resources for its research, development, and demonstration (RD&D). CCS is expected to be commercially available for large coal-fired power plants in the 2025-2030 periods.

Technically, it is possible to incorporate equipment to capture CO_2 in most types of new coal-based power plants. Depending on available space and other considerations, such equipment also might be able to be retrofitted to some existing coal-based plants. Since adding currently available CO_2 capture technologies will have significant impacts on the cost of electricity, as well as on plant output and efficiency, EPRI, the DOE and others are conducting research into less expensive, less energy-intensive, and more flexible CO_2 capture technologies. This research spans the range from development to demonstration.

CO_2 capture is only part of the CCS picture. Important work is proceeding around the world to identify potential storage sites and capacities, verify predicted CO_2 behavior in target geologic formations minimize or eliminate environmental impacts, and assess the cost and performance of monitoring programs. Geologic injection of CO_2 for enhanced oil recovery (EOR) has been a commercial practice for 35 years. These proven methods now are being modified to maximize the amount of CO_2 left securely in the ground at the conclusion of injection operations. Researchers are now investigating the viability of injection of CO_2 into deep, porous saline formations, which are much more prevalent than depleted oil and gas reservoirs.

The DOE's Regional Carbon Sequestration Partnerships (RCSPs) program is the centerpiece of the government's efforts to develop the infrastructure and knowledge base needed to place CCS technologies on the path to commercialization. Collectively, the seven RCSPs represent regions encompassing 97 percent of U.S. coal-fired CO_2 emissions, 97 percent of U.S. industrial CO_2 emissions, 96 percent of the total U.S. land mass, and essentially all of the geologic sequestration sites in the U.S. that are potentially available for CO_2 storage. The seven RCSPs span 42 states, four Canadian provinces, and two Indian nations. The RCSPs have over 350 partners from state and local governments, universities, utilities, oil companies, environmental organizations, and equipment developers. The RCSPs currently receive about 1/3 of their funding from companies representing the organizations noted above.

During the first phase of the three-phased program, the RCSPs characterized the potential for CO_2 storage in deep oil-, gas-, coal-, and saline-bearing formations. In the program's second phase, the RCSPs implemented a portfolio of small-scale geologic sequestration projects. The purpose of these tests was to validate that different geologic formations have the injectivity, containment, and storage effectiveness needed for long-term storage. The third phase will involve seven large-scale sequestration field tests that will demonstrate the long-term, effective, and safe storage of CO_2 in the major geologic formations throughout the U.S. and portions of Canada.

There are only a few large-volume CO_2 storage demonstrations, and none to date involves an integrated operation with a CO_2 capture system at a power plant. Research organizations around the world point to such demonstrations as the crucial link to commercialization. In addition, CO_2 storage requires resolution of many legal and regulatory issues. Some analysts believe these issues may prove to be the biggest obstacle to widespread commercialization of CCS technologies.

RD&D are also needed to improve the thermodynamic efficiency of coal-based power plants as a way to reduce CO_2 emissions. Until CCS technologies become commercially available, increased efficiency of power generation is the most predictable and cost effective method for CO_2 emissions reduction. Increased thermodynamic efficiency reduces the amount of CO_2 generated per unit of plant output.

Fuel Costs and CO_2 and Other Emissions

Economic analyses show that the dual strategy of improving generating efficiency and improving CO_2 capture system performance is the optimal path to competitive advanced coal-based power systems with CCS.

Ongoing RD&D for emission control systems has improved the environmental performance of coal-based plants to the point that near-zero emission (NZE) levels for traditional emissions now are seen as reasonable targets. In addition, because several CO_2 capture technologies require inlet flue gas with extremely low levels of SO_2 and NO_X, the need for technologies that reach NZE levels has become linked to commercializing CO_2 capture processes.

EPRI and the Coal Utilization Research Council have formulated a "roadmap" for developing advanced coal-based power systems with CCS. This roadmap identifies and sequences the necessary RD&D activities at the component, integrated system, and power plant levels for coal power technologies. Critical links between development efforts also have been identified.

To realize the benefits of competition, and to accommodate the cost and performance risks of any one technology, the electric power and other industries will require multiple, competing technologies. In addition, because fuel properties are a major driver in designing coal-based power plants, different technologies often are needed when different coals are used (in contrast to natural gas-fired plants, where fuel homogeneity allows for greater standardization). Three primary approaches to CO_2 capture are being considered, with competing technology developers leading the commercialization effort:

- Pre-combustion capture technologies are applied to pressurized synthesis gas, prior to combustion in the gas turbine of an integrated gasification combined cycle (IGCC) unit
- Post-combustion capture technologies are used to absorb CO_2 from flue gas, at atmospheric pressure, from coal-fired boilers using pulverized coal (PC), circulating fluidized bed (CFB), and other types of coal combustion systems
- Oxy-combustion technologies, applied to new or modified combustion power boilers, eliminate most of the nitrogen in air prior to combustion, thereby allowing direct compression of high CO_2 concentration flue gas following any final purification steps.

Some of these processes already are used in other industries, albeit at a smaller scale than is needed for power plants. This experience reduces the lead time and risk for scale-up. In addition, many researchers and technology developers are working on novel CO_2 capture technologies, raising the potential for new, more cost-effective breakthroughs.

EPRI's work has shown that no single advanced coal-based power generation technology holds clear-cut advantages across the full range of coal types and operating environments. The use of dedicated systems to capture CO_2 from electric power plants is a relatively new concept that has evolved only over the last decade. Historically, CO_2 separation only has been practiced in industrial gasification plants. This is why, today, "pre-combustion" CO_2 capture from IGCC plants is a more mature technology than "post-combustion" or "oxy-combustion" capture options for PC or CFB plants. Although it has been reported that IGCC with CO_2 capture holds an economic advantage for low-moisture bituminous coals, studies by EPRI and the Canadian Clean Power Coalition show that PC plants with post-combustion CO_2 capture are competitive for subbituminous and lignite coals (which have high moisture content and relatively lower heating value). These studies underscore the need for multiple technologies, as no single advanced coal-based generating technology will be optimized for all coal types.

Cost analyses can determine which technology will deliver the lowest levelized cost of electricity for a given fuel under the operating conditions of a specific location. Once the generation technology is selected, the unit can be specifically designed for a range of fuels (referred to as the design feedstock or design coal).

For the last three years, the more than 60 member organizations within several EPRI programs—in particular, the *CoalFleet for Tomorrow®* group—have examined in detail the technical and institutional barriers to advanced coal and CCS technologies, and have identified the critical RD&D pathways to overcome these barriers and, in turn, develop a set of competitive, commercially ready technology options. Many important development activities for advanced coal and CCS technologies already are under way, both collaboratively through EPRI and other organizations and independently by multiple electricity generators and technology developers across the globe.

Further, the power industry is working with EPRI to launch major demonstrations of advanced coal-based power generation and CCS technologies. The industry and EPRI are coordinating these technology demonstrations with the DOE. These demonstrations are the kinds of “big steps” urgently required to meet society’s need to expedite the commercial readiness of CCS to address CO_2 emissions. Given this urgency to develop and demonstrate CCS technologies, the need exists to accelerate the pace of RD&D and increase investment in advanced coal and CCS technologies to make them ready for widespread commercial deployment in the 2025-2030 periods.

Conclusions

Coal is the choice for new power generation worldwide. It is relatively inexpensive compared to other forms of energy and is easily transported and used. However, for coal to be used in a sustainable way in the future, and to limit greenhouse emissions, CCS technologies must be developed and made commercially available for use with large coal-based power generation technologies. Present RD&D programs, including those being implemented by EPRI and the DOE, will likely lead to CCS technologies becoming commercially available for such applications in the 2025-2030 time period. The NCC endorses work in this area as being critical for the timely development of commercially available CCS technologies. In order to accelerate the development of these technologies, a much more widespread RD&D program, at large scale, will be required.

As a public advisory committee to the Secretary of Energy initially chartered in 1984, The National Coal Council has compiled over 30 reports at the Secretary’s request on numerous issues affecting coal and U.S. energy policy. The factual information in this paper, and the conclusions based thereon, are drawn from these studies and the documents used to compile them, all of which have been submitted to the Secretary of Energy.