POWERSPAN®
Clean Energy Technology

Overview of ECO_2™ for CO_2 Capture

In May 2004, Powerspan Corp. and the U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) entered into a cooperative research and development agreement to develop a cost effective CO_2 removal process for coal-fired power plants. The regenerative process, called "ECO_2™", is readily integrated with Powerspan's ECO® process for multi-pollutant control, and uses an ammonia-based solution to capture CO_2 in flue gas and release it for enhanced oil recovery or other form of geological sequestration. The process can be applied to both existing and new coal-fired power plants and is particularly advantageous for sites where ammonia-based scrubbing of power plant emissions is employed.

ECO_2 is a scrubbing process that uses an ammonia-based (not an amine) solution to capture CO_2 from the flue gas. The CO_2 capture takes place after the NOx and SO_2 capture in Powerspan's ECO multi-pollutant control technology. Once the CO_2 is captured, the ammonium bicarbonate solution is regenerated to release CO_2 and ammonia (NH_3). The NH_3 is recovered and sent back to the scrubbing process, and the CO_2 is in a form that is sequestration ready. Ammonia is not consumed in the scrubbing process, and no separate by-product is created.

ECO_2 Commercialization Plan

Both Powerspan and the DOE have conducted laboratory testing of the CO_2 capture process, and Powerspan is preparing for pilot testing, which is scheduled to begin in early 2008. Powerspan laboratory testing of the CO_2 absorption process has demonstrated 90 percent CO_2 removal under conditions comparable to a commercial-scale absorber, confirming test results previously obtained by the DOE under similar conditions.

Pilot Test Program

In September 2005, Powerspan and FirstEnergy announced plans to pilot test the ECO_2 technology at FirstEnergy's R.E. Burger Plant in Shadyside, Ohio. In May 2006, FirstEnergy announced that its Burger Plant was selected as a carbon sequestration test site by the Midwest Regional Carbon Sequestration Partnership, one of seven regional partnerships set up by the U.S. DOE to research carbon sequestration projects throughout the country. These combined projects provide a first-time opportunity to demonstrate both CO_2 capture and sequestration at a conventional pulverized coal-fired power plant.

The ECO_2 pilot unit will process a 1-MW slipstream (20 ton CO_2/day) from the 50-MW Burger Plant ECO unit. The pilot program will demonstrate the ability of the CO_2 capture process to be integrated with the ECO multi-pollutant control process and will confirm process design and cost estimates.

- 1 MW equivalent, designed to capture 90% of incoming CO_2 (~20 tons/day)
- Purified CO_2 stream will be provided to Battelle/EPRI for pressurization and sequestration on site as part of the Midwest Regional Carbon Sequestration Partnership project, sponsored by U.S. DOE.

- Construction of ECO_2 pilot scheduled for completion by the end of 2007 with pilot testing beginning early in 2008.

Commercial Demonstration Program Plans

The following highlights the major aspects of the Company's plans to commercially demonstrate the ECO_2 process, based upon successful completion of the pilot scale testing in 2008-09:

- The ECO_2 commercial demonstration would nominally be a 100 MW system, capturing 90% CO_2 (2,000 tons/day, or 500,000 tons/year at 70% capacity factor), making this system among the largest CO_2 capture systems in the world.
- Design of the commercial demonstration would begin in 2009 with operations commencing in 2011.
- The commercial demonstration would preferably be installed where an ECO unit is located and also within close proximity to an enhanced oil recovery (EOR) site. CO_2 sold for EOR is worth up to $30/ton with $50/barrel oil prices.

Plans for Full-Scale Commercial ECO_2 Systems

With success of the pilot and commercial demonstration phases, it is reasonable to project availability of full-scale ECO_2 systems beginning in 2015 (assuming a design start in 2012).

Projected ECO_2 Capital Cost

Today, Powerspan would target full-scale ECO_2 system capital costs in the $300-$500/kW range, or $150-$250 million for a 500-MW plant (assuming ECO is already installed).

Background on CO_2 Capture Economics & Research

CO_2 Capture Economics

In February 2005, DOE published *An Economic Scoping Study for CO_2 Capture Using Aqueous Ammonia* that compared the cost of CO_2 capture and sequestration for a new super-critical pulverized coal-fired power plant using conventional air pollution control equipment and amine (MEA, monoethanolamine) based CO_2 absorption, versus a multi-pollutant control system such as ECO and CO_2 removal using ammonia (i.e. ECO_2). Their economic analysis projects that 90% CO_2 capture and sequestration with the conventional pollution control systems and MEA would cost $47/ton of CO_2 removed, and the cost of electricity would be 7.6 cents/kWh. By comparison, the estimated costs for the ECO system with ammonia-based CO_2 capture and sequestration were $14/ton of CO_2 removed and 5.5 cents/kWh for electricity. Thus the projected incremental costs of CO_2 removal with ECO are less than one-third of the costs for conventional technology on pulverized coal-fired plants.

CO_2 Capture Research

NETL researchers authored a paper entitled *Aqua ammonia process for simultaneous removal of CO_2, SO_2, and NOx*. This paper documents research conducted at NETL labs on the use of aqua ammonia for absorption of CO_2. The paper reaches the following conclusions:

1. The traditional monoethanolamine (MEA) process for CO_2 removal suffers the disadvantages of low CO_2 loading capacity (kg CO_2 absorbed per kg absorbent), high equipment corrosion rate, amine degradation by SO_2, NO_2, HCl, HF and O_2 in the flue gas (which requires a high absorbent makeup rate), and high energy consumption during absorbent regeneration.
2. By comparison, aqua ammonia, which Powerspan uses in the ECO_2 process, has higher loading capacity, does not pose a corrosion problem, does not suffer degradation in a flue gas environment (minimizing absorbent makeup), requires much less energy to regenerate, and costs much less than MEA.
3. Specifically, the aqua ammonia process compared to MEA:
    a. Has CO_2 absorption capacity up to two times greater;
    b. Requires 49% to 64% less heat to release CO_2 and regenerate absorbent; and
    c. Has reagent makeup costs of approximately one sixth.
4. Another major benefit is that removal of other pollutants (principally SO_2 and NOx) could be integrated with the aqua ammonia process for CO_2 removal (i.e. using the ECO multi-pollutant control technology).

Both NETL and Powerspan have research teams assigned to conduct bench-scale testing of the process to optimize parameters for CO_2 capture and regeneration of the ammonium carbonate solution to release CO_2 for enhanced oil recovery or sequestration.