# GREENIDGE MULTI-POLLUTANT CONTROL PROJECT

U.S. DOE Cooperative Agreement No. DE-FC26-06NT41426

CONSOL Energy Inc.
Research & Development
4000 Brownsville Road
South Park, PA 15129-9566

D. P. Connell
Principal Investigator
(412) 854-6559
danielconnell@consolenergy.com

**QUARTERLY PROGRESS REPORT**
**FOR WORK PERFORMED DURING THE PERIOD**
**October 1, 2006 to December 31, 2006**

January 29, 2007

## 1.0 Executive Summary

As part of the Greenidge Multi-Pollutant Control Project, CONSOL Energy Inc. (CONSOL), AES Greenidge LLC (AESG), and Babcock Power Environmental Inc. (BPEI) are installing and testing an integrated multi-pollutant control system on one of the nation's smaller existing coal-fired power plants - the 107-MWe AES Greenidge Unit 4 (Boiler 6). The overall goal of this approximately 2.5-year project, which is being conducted as part of the U.S. Department of Energy's (DOE's) Power Plant Improvement Initiative (PPII), is to demonstrate that the multi-pollutant control system being installed, which includes a hybrid selective non-catalytic reduction / selective catalytic reduction (SNCR/SCR) system and a Turbosorp® circulating fluidized bed dry scrubbing system with recycled baghouse ash and activated carbon injection, can cost-effectively reduce emissions of $NO_x$, $SO_2$, Hg, acid gases ($SO_3$, HCl, HF), and particulate matter from coal-fired electrical generating units (EGUs) with capacities of 50 MWe to 600 MWe. Smaller coal-fired units, which constitute a significant portion of the nation's existing generating capacity, are increasingly vulnerable to retirement or fuel switching as a result of increasingly stringent state and federal environmental regulations. The Greenidge Project will demonstrate the commercial readiness of an emissions control system that is particularly suited, because of its low capital and maintenance costs and small space demands, to meet the requirements of this large group of existing EGUs. All funding for the project is being provided by the U.S. DOE, through its National Energy Technology Laboratory (NETL), and by AES Greenidge.

The multi-pollutant control system is depicted in Figure 1. The $NO_x$ control system consists of commercially available combustion modifications (installed outside of the scope of the DOE project), a urea storage system, a urea dilution and injection system (SNCR), and a single-bed, in-duct SCR reactor that is fed by ammonia slip from the SNCR process. The Turbosorp® system for $SO_2$, $SO_3$ (visible emissions control), mercury, HCl, HF, and particulate matter control consists of a hydrator and hydrated lime feed system, a process water system, the Turbosorp® vessel, a baghouse for particulate control, an ash recirculation system to recycle solids collected in the baghouse to the Turbosorp® vessel, and an activated carbon injection system for mercury control. A booster fan is also being installed to overcome the pressure drop resulting from the installation of the SCR catalyst, Turbosorp® scrubber, and baghouse.

Specific objectives of the project are as follows:

- Demonstrate that the hybrid SNCR/SCR system, in combination with combustion modifications, can reduce high-load $NO_x$ emissions from the 107-MWe AES Greenidge Unit 4 to ≤0.10 lb/mmBtu (a reduction of ≥60% following the combustion modifications) while the unit is firing >2%-sulfur coal and co-firing up to 10% biomass.
- Demonstrate that the Turbosorp® circulating fluidized bed dry scrubber can remove ≥95% of the $SO_2$ emissions from AES Greenidge Unit 4 while the unit is firing >2%-sulfur coal and co-firing up to 10% biomass.

- Demonstrate ≥90% mercury removal via the co-benefits achieved by the SNCR/SCR and Turbosorp® circulating fluidized bed dry scrubber (with baghouse) systems and, as required, carbon or other sorbent injection.
- Demonstrate ≥95% removal of acid gases ($SO_3$, HCl, and HF) by the Turbosorp® circulating fluidized bed dry scrubber.
- Evaluate process economics and performance to demonstrate the commercial readiness of an emission control system that is suitable for meeting the emission reduction requirements of boilers with capacities of 50 MWe to 600 MWe.

This quarterly report, the third to be submitted for the Greenidge Multi-Pollutant Control Project, summarizes work performed on the project between October 1 and December 31, 2006. During the period, work at the AES Greenidge site transitioned from construction, which occupied much of the first half of the quarter, to start-up and commissioning, which predominated during the second half. The tie-in outage for the multi-pollutant control system was completed on November 18, 2006, according to schedule. During the outage, installation of the SNCR system and construction of the in-duct SCR reactor were completed, and the Turbosorp® system and associated equipment were integrated with the existing plant. Start-up of the multi-pollutant control system was delayed by several weeks because of an electrical problem with the soft start for the booster fan; however, this problem was resolved in early December, and start-up and commissioning activities were proceeding normally as of the end of the reporting period. The project team requested and received approval from DOE to continue into the project's second (and final) budget period, effective January 2007. We expect to complete start-up and begin operation and testing of the multi-pollutant control system during the upcoming quarterly reporting period.

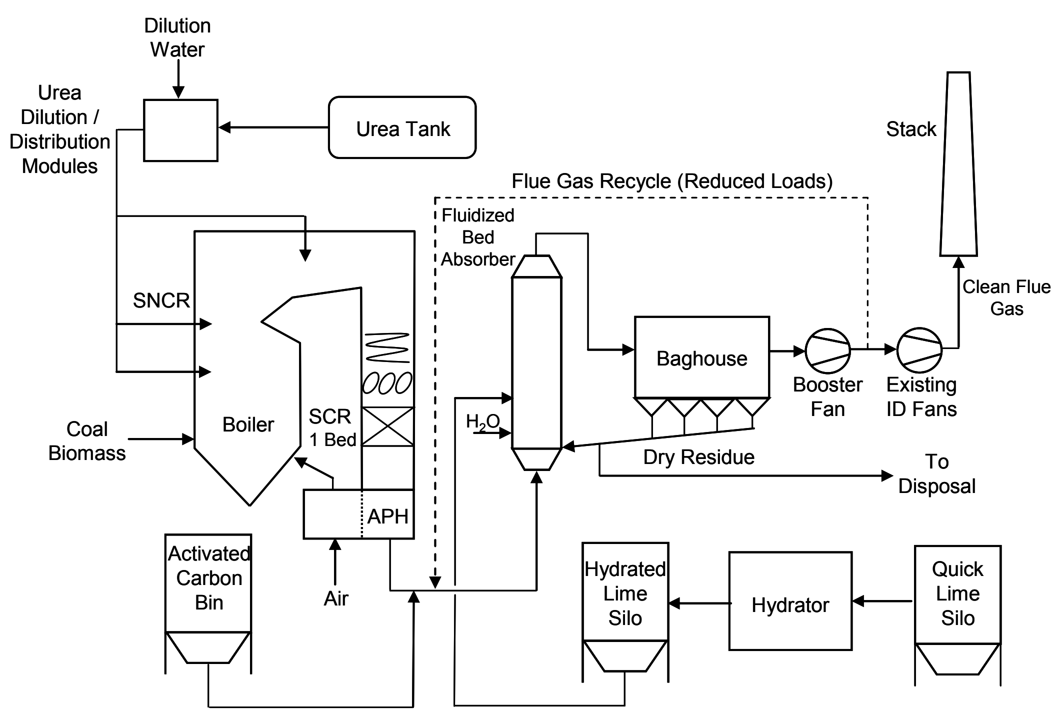



**Figure 1.** Schematic of the multi-pollutant control system being demonstrated at AES Greenidge.

## 2.0 Work Performed and Results Obtained During the Reporting Period

Highlights of the Greenidge Multi-Pollutant Control Project during the period from October 2006 through December 2006 included completion of the tie-in outage for the multi-pollutant control system, commencement of start-up and commissioning of the system, and receipt of DOE approval for continuation into the project's second budget period. Project progress was delayed for several weeks by an electrical problem encountered during start-up of the booster fan; however, this problem was overcome and start-up activities were proceeding normally as of the end of the quarter. Work performed and results obtained between October 1, 2006, and December 31, 2006, are described below by Statement of Project Objectives task number.

Tasks 1.1 and 2.1 – Project Management

During the fourth quarter of calendar year 2006, the project team received DOE approval for continuation into the project's second (and final) budget period, during which operation and testing of the multi-pollutant control system will be conducted. The team submitted a continuation application to DOE on November 7 requesting such approval. DOE completed its review of the application and on December 22 issued a Cooperative Agreement modification approving continuation into the second budget period, effective January 2, 2007, and authorizing funding for the balance of the project. The project budget was also revised to remove the $359,077 of unsupported costs that were identified in DOE's September 18, 2006, letter to CONSOL, as well as $25,135 of indirect costs that had been applied to this unsupported amount. The total project cost is now $32,742,976, of which $14,341,423 (43.8%) is being contributed by DOE and $18,401,553 (56.2%) is being contributed by AESG.

Presentations highlighting the project and the design of the multi-pollutant control system that is being demonstrated at AES Greenidge were given at two technical meetings during the quarter. On October 17, Dan Connell of CONSOL gave a presentation titled "Design of an Integrated Multi-Pollutant Control System for Reducing Emissions of $SO_2$, $NO_x$, Hg, Acid Gases, and Particulate Matter from Smaller Coal-Fired Power Plants" at the American Filtration and Separations Society's 2006 fall conference on Separations Processes for the Power Generation Industry, which was held in Pittsburgh, PA. On December 13, Bill Rady of AESG gave a presentation titled "AES Greenidge Multi-Pollutant Control Project" at the December luncheon of the Air & Waste Management Association's Genesee Finger Lakes Chapter, which was held in Rochester, NY. These presentations are included as Appendices A and B to this report. Also during the quarter, our abstract titled "Initial Cost and Performance Results from the Greenidge Multi-Pollutant Control Project" was accepted for presentation at the 2007 Electric Power Conference & Exhibition (May 1-3, 2007, Chicago, IL), and our abstract titled "The Greenidge Multi-Pollutant Control Project: Key Technical and Economic Features of a New Approach for Reducing Emissions from Smaller Coal-Fired Units" was accepted for presentation at the Air & Waste Management Association's 100th Annual Conference & Exhibition (June 26-29, 2007, Pittsburgh, PA).

A progress review meeting including representatives from DOE-NETL (Wolfe Huber and Mike McMillian), CONSOL (Dick Winschel and Dan Connell) and AESG (Doug Roll, Bill Rady, and Chuck Sjoberg) was held at the AES Greenidge site on November 2. On December 20, CONSOL, AESG, and BPEI met at the Greenidge site to review start-up progress, work on the DOE design reports, discuss plans for guarantee testing, and inspect the sampling locations in the plant to ensure sufficient access for testing. Several additional sampling ports will be installed around the SCR and at the air heater outlet in January 2007, prior to the guarantee tests, to facilitate testing.

Work on drafting the Preliminary Public Design Report for the project continued, although the report was not completed during the quarter as originally planned. We expect to issue the Preliminary Public Design Report and draft the Final Public Design Report during the first quarter of calendar year 2007.

Task 1.2 – Total Process Definition and Design

As discussed in the last quarterly progress report, this task is complete.

Task 1.3 – Procurement

The final major procurement milestone was accomplished on November 6, when the 26 SCR catalyst modules were shipped to the AES Greenidge site. Remaining shipments of miscellaneous other items, including the airslide heaters and the catalyst tracks, catalyst cart, and catalyst hoist for the SCR system, were also completed in October and November. Task 1.3 is now complete.

Task 1.4 – Environmental/Regulatory/Permitting

As discussed in the project's first quarterly progress report, all permits and clearances required for construction of the multi-pollutant control facility were obtained. In addition, AESG must amend its Title V air permit as part of the regularly scheduled renewal process for that permit in order to reflect the emission requirements set forth in its consent decree with the State of New York. AESG has been working with the New York State Department of Environmental Conservation to effect this amendment, and no problems are anticipated. AESG is also working to modify water discharge and solid waste permits as required to reflect changes resulting from the installation of the multi-pollutant control system. These modifications will be completed once operating data become available to inform the permitting process.

Task 1.5 – Environmental Information Volume

As discussed in the project's first quarterly progress report, this task is complete.

Task 1.6 – Baseline Testing

As discussed in the project's first quarterly progress report, this task is complete.

Tasks 2.2 and 2.3 – General Civil/Structural and Process System Construction

Tasks 2.2 and 2.3 were largely complete as of the end of the fourth quarter of calendar year 2006. The AES Greenidge Unit 4 (Boiler 6) major fall tie-in outage, which began on September 29, 2006, at the end of the third calendar quarter, continued into the current reporting period and was completed on Saturday, November 18, according to schedule. Most of the civil/structural and process system construction work performed during the period occurred during this approximately 1.5-month outage period. This work included installation of the urea injection system for the SNCR process, installation of the in-duct SCR reactor between the plant's existing economizer and air heaters, tie-in of the Turbosorp® system, baghouse, ash recirculation system, and booster fan to the existing plant, and completion of various electrical installation tasks.

Installation of the hybrid SNCR/SCR system was completed during the tie-in outage period. Demolition work was carried out during the first half of October to enable the SNCR injectors and the SCR reactor to be installed. Contractors erected scaffolding around Boiler 6 during the first week of October, and they removed lagging and insulation during that week from areas where the SNCR injectors would be installed. Demolition of ductwork between the economizer outlet and air heater inlet also was completed during the first two weeks of the month to allow for installation of the in-duct SCR reactor. By October 21, workers had finished modifying the Boiler 6 water wall to create penetrations for the multiple nozzle lances and urea injection nozzles for the SNCR system.

Installation of the SNCR injectors and multiple nozzle lances was completed by mid-November. All piping required for the SNCR system was in place by November 17, and workers finished re-installing insulation and lagging on that day as well. Also during the quarter, installation was completed for the urea storage tank and urea circulation module, which had been set in place outside the boiler building during the last quarterly reporting period. Figure 2 presents a photograph of the outdoor urea storage and circulation area as of November 2.

Installation of the in-duct SCR system, which was the critical path activity of the tie-in outage, was completed on schedule. During the month of October, support steel for the SCR reactor was erected in the boiler building; the expansion joint at the economizer outlet was installed, and construction of the SCR reactor casing commenced. Construction was completed during the first half of November. The Delta Wing static mixers had been installed by November 11, and workers loaded catalyst into the reactor and finished seal welding the reactor casing during the week of November 12. The sonic horns, catalyst hoist, and access platforms were also installed, and the SCR reactor was insulated and lagged. Figure 3 presents a photograph taken on October

27, when construction of the SCR reactor was just beginning. The photograph presented in Figure 4, taken on December 1, shows the completed reactor.


**Figure 2.** Photograph showing the urea storage and circulation area as of November 2, 2006.

Construction work during the outage also included tie-in of the Turbosorp® system and associated equipment into the existing plant. Demolition of ductwork from around the existing electrostatic precipitator (ESP) was completed by October 17 to allow for tie-in of the Turbosorp® system, and installation of the ductwork (and associated expansion joints) connecting the air heater outlet duct to the inlet of the Turbosorp® vessel was completed during the week of November 12. In addition, the last section of ductwork connecting the new booster fan to the existing induced draft (ID) fans was installed in mid-October.

All major electrical equipment wiring for the multi-pollutant control system had been completed by the end of October. During that month, electricians set the control panel and variable frequency drive panel for the hydrator in place, pulled cable in the baghouse penthouse, modified the old 2400V motor control centers to allow for connection of the new motor control centers, finished all remaining terminations for the 480V switchgear, completed hi-pot testing of the 2300V feeder cables, and successfully energized the 2300V transformer and bumped the booster fan motor. The 480V motor control center was energized during the first week of November.

**Figure 3.** Photograph taken on October 27, 2006, at the start of SCR reactor construction.

**Figure 4.** Photograph taken on December 1, 2006, showing the completed SCR reactor.

Also during the reporting period, miscellaneous remaining construction activities related to the Turbosorp® system, baghouse, lime hydration system, ash recirculation system, and activated carbon injection system were completed. For example, workers finished installing the activated carbon feed and injection system, the heating system for the ash recirculation airslides, the water spray nozzles for the Turbosorp® system, and the baghouse plenum doors. They also finished installing piping for the lime hydration system and aligned and charged the ball mill (although this was not completed until December, after the end of the tie-in outage). The airslides and various ductwork sections were insulated and lagged, and piping tie-ins (e.g., for service air, instrument air, potable water, fire protection, etc.) were completed. The 200-ton crane was disassembled and removed from the AES Greenidge site during the first half of November, and civil work for the quicklime and urea unloading area, which had been delayed until the demobilization of this crane, was completed. Figure 5 presents a photograph of the unloading area that was taken on November 17, shortly after the area was paved.

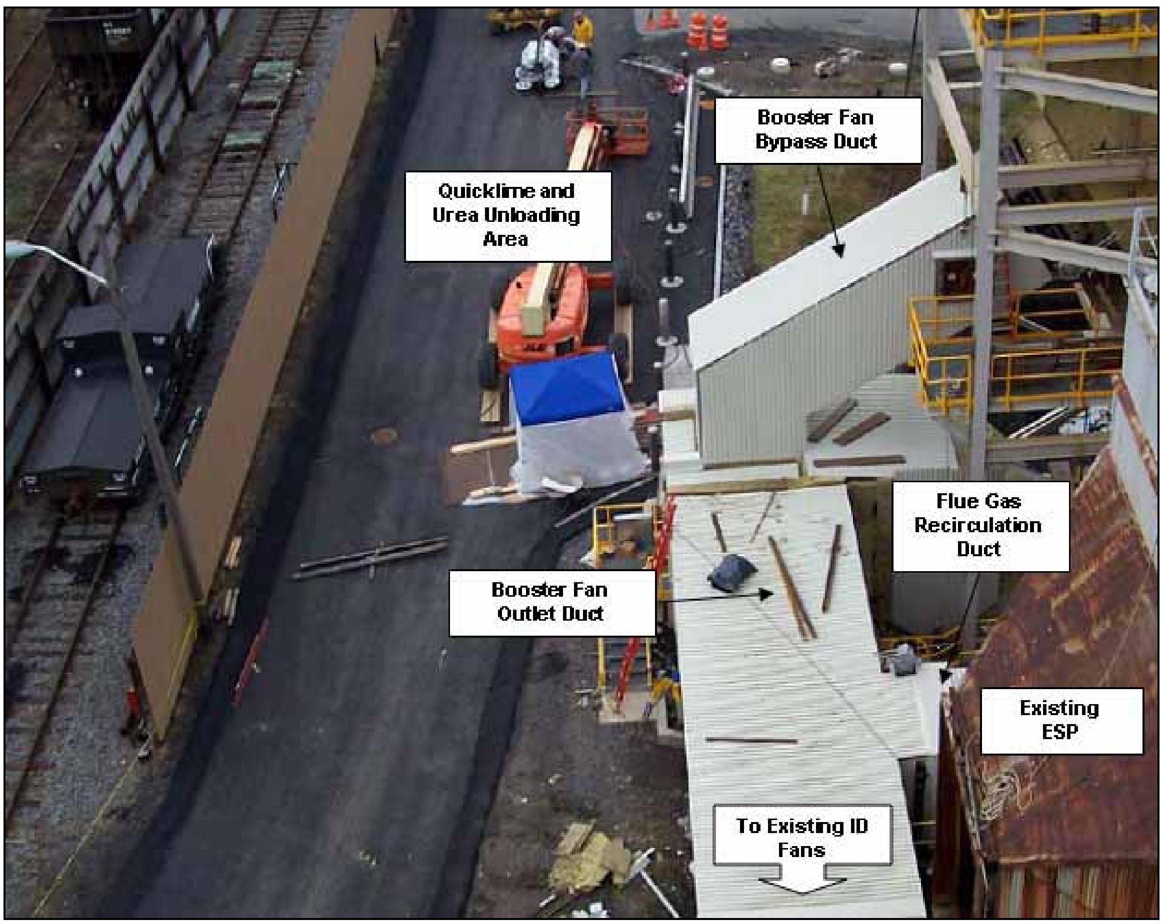



**Figure 5.** Photograph showing the quicklime and urea unloading area as of November 17, 2006. Also visible are the booster fan bypass duct and portions of the booster fan outlet ductwork, flue gas recirculation duct, and existing electrostatic precipitator (which was retired in place).

The tie-in outage ended at about 10:00 pm on Saturday, November 18, when BPEI released Boiler 6 to AES Greenidge for operation. Figure 6 presents a photograph of the outdoor portion of the multi-pollutant control system that was taken on December 8, after construction was essentially finished. As of the end of the quarterly reporting period, all but one of the major milestones associated with Tasks 2.2 and 2.3 had been completed. The sole remaining milestone requires that BPEI achieve Mechanical Completion of the multi-pollutant control system as defined in their EPC agreement with AESG. The delay in achieving Mechanical Completion, which requires that all components of the multi-pollutant control system are ready to be turned over to AES Greenidge for full, safe, and reliable start-up and operation, is largely attributable to post-outage problems that were encountered with the booster fan soft start (as discussed below under Task 2.4) and to modifications that had to be made to the lime hydration system after initial testing of that system. We expect that Mechanical Completion will be achieved in late January or early February 2007.

**Figure 6.** Photograph taken on December 8, 2006, showing the multi-pollutant control system as viewed from the northwest. The Turbosorp® absorber vessel, lime storage and hydration system, baghouse, and top of the urea storage tank are all visible in the shot.

Task 2.4 – Plant Start-Up and Commissioning

Much of the Task 2.4 work performed during the fourth quarter of calendar year 2006 occurred during the second half of the quarter, following the completion of the tie-in outage at AES Greenidge. First, however, operating and maintenance manuals for the multi-pollutant control system were completed in October, and on November 2-3 and 6-7, BPEI held training sessions for AES Greenidge employees regarding operation and maintenance of the multi-pollutant control system.

Start-up and commissioning activities intensified in mid-November. The baghouse filter bags were pre-coated on November 17 and 18, and commissioning tasks were performed successfully for a number of equipment items (e.g., air slide blowers, various SNCR system components, process water pump, etc.) associated with the multi-pollutant control system during the second half of that month. As discussed above, BPEI released Boiler 6 to AES Greenidge for operation at about 10:00 pm on Saturday, November 18. However, two issues delayed start-up of Unit 4 and of the multi-pollutant control system. The Unit 4 turbine outage, which was conducted by AESG simultaneously to the tie-in outage (but outside of the scope of the DOE project), ran several days behind schedule. The turbine was released to AES Greenidge on the evening of Wednesday, November 22, but problems with the turbine supervisory instrumentation and the hydraulic trip circuit delayed start-up by another week. These problems were resolved, however, and the Unit 4 generator was synchronized to the power grid on Thursday, November 30. Further delays arose from a problem with the soft start for the booster fan, which was within the scope of the DOE project. On Friday, November 24, an attempted start-up of the fan caused operation of the station service differential protection relay, blacking out the entire plant. Subsequent testing of the station service transformer and differential protection relay indicated no problems, and power to the plant was restored. AES Greenidge was able to operate Unit 4 at reduced load while bypassing the booster fan, but actual start-up of the multi-pollutant control system could not occur until the fan was operational. BPEI, Industry and Energy Associates (IEA), and Rockwell Automation worked throughout late November and early December to resolve the problem, and they succeeded in doing so on December 4, when workers discovered that the soft start controller was not properly grounded and successfully corrected the problem and started the fan.

Start-up and commissioning activities proceeded normally throughout the rest of December. After synchronizing Unit 4 to the power grid on December 7, AESG gradually ramped up the unit's load while Babcock Power commissioned the new combustion system. This combustion system work is being conducted outside of the DOE scope, but must be completed before start-up of the hybrid SNCR/SCR system can occur. As of late December, Unit 4 was operating at full load, and the new low-$NO_x$ burners were achieving a $NO_x$ emission rate of about 0.27 lb/mmBtu, close to the target rate of 0.25 lb/mmBtu. Combustion system optimization is scheduled to be completed in January 2007. Regarding pollution control equipment within the DOE scope, the baghouse was in service throughout the month of December, and various commissioning activities were completed for the SNCR system, Turbosorp® system, and lime hydration system, although none of these systems started up during the month. On December 15, workers established a fluidized bed in the Turbosorp® absorber using accumulated fly ash (no hydrated lime was injected) and successfully operated the Turbosorp® system for a time with water injection and baghouse ash recycling while Unit 4 was running at about 65 MW. On December 20, the first shipment of pebble lime was delivered to the Greenidge site; BPEI was working at the end of the quarter to improve the lime unloading system in response to several problems that were encountered while transporting the lime from the delivery truck to the storage silo. As of the end of the reporting period, start-up and commissioning were about 2-3 weeks behind schedule because of the delays caused by the problems with the booster fan soft start and turbine outage and the reduced workforce on site during the end-of-December holiday period. All major remaining start-up and commissioning activities, including completion of combustion system optimization, start-up of the Turbosorp® system, start-up of the lime hydration system, and start-up of the hybrid SNCR/SCR system, are scheduled for January 2007.

# 3.0 Status Reporting

## 3.1 Cost Status

Table 1 summarizes the cost status of the Greenidge Multi-Pollutant Control Project through the end of the fourth quarter of calendar year 2006. As reported in the last quarterly progress report, unsupported direct costs totaling $359,077 that were identified in DOE's September 18, 2006, letter to CONSOL were removed from the baseline costs for the second quarter of 2006. Per Amendment No. A002 to the DOE Cooperative Agreement for the project (DE-FC26-06NT41426), which was issued on December 22, 2006, indirect costs totaling $25,135 that were applied to these indirect costs have also been removed from the baseline costs for the second quarter of 2006. Cumulative planned baseline costs for all subsequent quarters were revised accordingly. Table 1 shows the resulting updated baseline cost plan; this plan will be used in all future quarterly progress reports. The costs reported in Table 1 also reflect a deduction of $25,135 from the actual incurred costs for the second quarter of calendar year 2006, corresponding to the removal of the unsupported indirect costs identified above.

As shown in Table 1, actual incurred costs for the fourth quarter of calendar year 2006 were $1,122,072 less than baseline planned costs for that quarter, and cumulative actual incurred costs were $2,480,074 less than cumulative planned costs as of the end of the quarter. This variance does not mean that the project was more than $2 million under budget as of December 2006; rather, it results in large part from the fact that BPEI did not achieve Mechanical Completion of the multi-pollutant control system, which had been scheduled to occur during the quarter, and therefore did not realize the approximately $2 million payment associated with this milestone. (The Mechanical Completion milestone has a large associated cost because of its importance in signifying that all components of the multi-pollutant control system are ready to be turned over to AES Greenidge for full, safe, and reliable operation; hence, missing it inevitably causes a substantial variance). Cumulative project administration costs were also less than budgeted through the end of December 2006, largely because the Cooperative Agreement for the project was signed later than anticipated, contributing to the cumulative variance shown in Table 1.

In spite of the approximately $2 million variance resulting from the missed Mechanical Completion milestone, the magnitude of the non-cumulative cost variance for the fourth quarter of 2006 was less than $2 million, because BPEI succeeded in catching up on several behind-schedule activities (i.e., preparation of operating and training manuals, training of plant staff, and completion of baghouse and lime hydration system construction) during the reporting period. Hence, the costs associated with these activities were incurred during the current quarter rather than during the previous quarter, thereby offsetting a portion of the variance caused by the missed Mechanical Completion milestone.

As discussed in Section 2.0, we expect that Mechanical Completion will be achieved during the upcoming reporting period, and that the magnitude of the project's cumulative cost variance will correspondingly decrease during that period.

### 3.2 Milestone Status

The critical path project milestone plan (from the Statement of Project Objectives) and status for the Greenidge Multi-Pollutant Control Project are presented in Table 2. As shown in the table and discussed in the last quarterly progress report, the second of the project's six critical path project milestones ("Commence tie-in outage"), which was planned for the current quarterly reporting period, was actually achieved on Friday, September 29, at the end of the last quarterly reporting period (third quarter of calendar year 2006). Hence, both of the project's critical path milestones for calendar year 2006 were accomplished ahead of the planned completion dates for these milestones. The next critical path project milestone calls for guarantee and performance testing of the multi-pollutant control system to begin during the first quarter of calendar year 2007. We do not anticipate that any changes in the project schedule will be required to complete this critical path milestone.

**Table 1.** Cost plan/status for the Greenidge Multi-Pollutant Control Project.

| Baseline Reporting Quarter | YEAR 1 Start: 1/1/2006 End: 12/31/2006 | | | | YEAR 2 Start: 1/1/2007 End: 12/31/2007 | | | | YEAR 3 Start: 1/1/2008 End: 12/31/2008 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2[a] | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **Baseline Cost Plan By Calendar Quarter** | | | | | | | | | | | | |
| Federal Share | | $7,276,205 | $1,806,841 | $2,135,468 | $1,581,828 | $365,626 | $239,208 | $228,040 | $235,068 | $292,521 | $176,448 | $4,170 |
| Non-Federal Share | | $9,336,136 | $2,318,366 | $2,740,030 | $2,029,651 | $469,137 | $306,930 | $292,599 | $301,617 | $375,335 | $226,402 | $5,351 |
| Total Planned (Federal and Non-Federal) | | $16,612,341 | $4,125,207 | $4,875,498 | $3,611,479 | $834,763 | $546,138 | $520,639 | $536,685 | $667,856 | $402,850 | $9,521 |
| Cumulative Baseline Cost | | $16,612,341 | $20,737,548 | $25,613,047 | $29,224,525 | $30,059,288 | $30,605,426 | $31,126,065 | $31,662,750 | $32,330,606 | $32,733,456 | $32,742,976 |
| **Actual Incurred Costs[b]** | | | | | | | | | | | | |
| Federal Share | | $6,610,049 | $1,878,193 | $1,644,001 | | | | | | | | |
| Non-Federal Share | | $8,481,387 | $2,409,918 | $2,109,425 | | | | | | | | |
| Total Incurred Costs-Quarterly (Federal and Non-Federal) | | $15,091,436 | $4,288,111 | $3,753,426 | | | | | | | | |
| Cumulative Incurred Costs | | $15,091,436 | $19,379,547 | $23,132,973 | | | | | | | | |
| **Variance[c]** | | | | | | | | | | | | |
| Federal Share | | ($666,156) | $71,352 | ($491,467) | | | | | | | | |
| Non-Federal Share | | ($854,749) | $91,552 | ($630,605) | | | | | | | | |
| Total Variance-Quarterly (Federal and Non-Federal) | | ($1,520,905) | $162,904 | ($1,122,072) | | | | | | | | |
| Cumulative Variance | | ($1,520,905) | ($1,358,001) | ($2,480,074) | | | | | | | | |

*Notes:* Some numbers may not add perfectly because of rounding. [a]Costs for Q2 2006 include costs for that quarter as well as pre-award costs incurred beginning in January 2002. Unallowable direct costs totaling $359,077 and indirect costs totaling $25,135 that were applied to these direct costs have been removed from the baseline costs for Q2 2006, consistent with Amendment No. A002 to Cooperative Agreement DE-FC26-06NT41426. [b]Actual incurred costs are all costs incurred by the project during the quarter, regardless of whether these costs were invoiced to DOE as of the end of the quarter. [c]Negative variance, ( ), means that actual incurred costs are less than baseline planned costs.

**Table 2.** Milestone plan / status report.

| Critical Path Project Milestone Description | Project Duration - Start: 5/19/06 End: 10/18/08 | | | | | | | | | | | | Planned Start Date | Planned End Date | Actual Start Date | Actual End Date | Comments (notes, explanation of deviation from baseline plan) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2006 | | | | 2007 | | | | 2008 | | | | | | | | |
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | | | | | |
| Initiate scrubber system installation | | A | P | | | | | | | | | | 9/30/06 | 9/30/06 | 5/30/06 | 5/30/06 | |
| Commence tie-in outage | | | A | P | | | | | | | | | 12/31/06 | 12/31/06 | 9/29/06 | 9/29/06 | See text under Section 3.2. |
| Begin guarantee/performance testing | | | | | P | | | | | | | | 3/31/07 | 3/31/07 | | | |
| Begin routine plant operation and data collection for long-term testing | | | | | | P | | | | | | | 6/30/07 | 6/30/07 | | | |
| Begin follow-up testing | | | | | | | | | | P | | | 6/30/08 | 6/30/08 | | | |
| Complete analyses of process performance and economics | | | | | | | | | | | P | | 9/30/08 | 9/30/08 | | | |

NOTE: “A” indicates actual completion; “P” indicates planned completion.

## 4.0 Significant Accomplishments during the Reporting Period

Because the project was still in its procurement and construction phases during the reporting period, no results concerning the performance of the multi-pollutant control facility are yet available. Significant progress-related accomplishments during the period, which are described more fully in Section 2.0 above, are as follows:

- Receipt of DOE approval for continuation into the project's second budget period
- Presentation of the project and multi-pollutant control system design at two technical meetings
- Completion of Task 1.3 – Procurement
- Completion of SNCR construction
- Completion of SCR construction
- Tie-in of the Turbosorp® system and associated equipment to the existing plant
- Completion of the AES Greenidge Unit 4 tie-in outage on November 18, 2006, as scheduled
- Completion of the operating and maintenance manuals and of training at AES Greenidge
- Start-up of the baghouse and booster fan
- Commencement of commissioning for the hybrid SNCR/SCR system, Turbosorp® system, and lime hydration system

## 5.0 Problems/Delays and Actions Taken/Planned to Resolve Them

As described in detail under Section 2.0 above, two problems were encountered during the quarterly reporting period that resulted in a minor delay in project progress. First, although the tie-in outage for the multi-pollutant control system was completed according to schedule on November 18, 2006, the Unit 4 turbine outage, which was conducted simultaneously by AESG outside of the scope of the DOE project, ran several days behind schedule, delaying start-up of the unit after the outage. Moreover, a grounding problem with the controller for the booster fan soft start prevented operation of the fan (and hence, start-up of most of the multi-pollutant control system) during the post-outage period. BPEI and its subcontractors devoted immediate attention to this problem, and it was resolved in early December.

These problems/delays caused schedule slippage of approximately 2-3 weeks. However, we still expect to be able to begin operation and testing of the multi-pollutant control system during the next quarterly reporting period and to satisfy our next critical path project milestone ("Begin guarantee/performance testing") during that quarter as planned. Guarantee testing is now anticipated to begin in February 2007, rather than in January 2007 as originally scheduled.

## 6.0 Products Produced and Technology Transfer Activities Accomplished During the Reporting Period

As discussed in Section 2.0 above, presentations on the project and on the design of the multi-pollutant control system that is being demonstrated at AES Greenidge were given at the American Filtration and Separations Society's 2006 fall conference on Separations Processes for the Power Generation Industry, which was held in Pittsburgh, PA, in October, and at the December luncheon of the Air & Waste Management Association's Genesee Finger Lakes Chapter, which was held in Rochester, NY. Copies of these presentations are included in Appendices A and B, respectively, of this report.

# APPENDIX A

## *Design of an Integrated Multi-Pollutant Control System for Reducing Emissions of $SO_2$, $NO_x$, Hg, Acid Gases, and Particulate Matter from Smaller Coal-Fired Power Plants*

Presented at the American Filtration and Separations Society's Fall Conference on Separations Processes for the Power Generation Industry, Pittsburgh, PA, October 17-18, 2006.

# Design of an Integrated Multi-Pollutant Control System for Reducing Emissions of $SO_2$, $NO_x$, Hg, Acid Gases, and Particulate Matter from Smaller Coal-Fired Power Plants


**Daniel P. Connell**
*CONSOL Energy Inc. Research & Development*

**Douglas J. Roll, P.E., and William B. Rady**
*AES Greenidge LLC*

**Richard F. Abrams**
*Babcock Power Environmental Inc.*



AFS Fall Topical Conference
Separations Processes for the Power Generation Industry
October 17-18, 2006, Pittsburgh, PA


## The Greenidge Multi-Pollutant Control Project

- Power Plant Improvement Initiative
  - Cost-shared collaboration between U.S. DOE and industry
  - Commercial demonstration of coal-based technologies
  - Goal: Help to ensure the reliability of the nation's energy supply by improving the efficiency, cost-competitiveness, and environmental performance of new and existing coal-fired electric generating facilities
- Greenidge Project
  - DOE Cooperative Agreement signed May 2006
  - Goal: Demonstrate a multi-pollutant control system that can cost-effectively reduce emissions of $NO_x$, $SO_2$, mercury, acid gases ($SO_3$, HCl, HF), and particulate matter from smaller coal-fired power plants

## Existing U.S. Coal-Fired EGUs
### 50-300 $MW_e$

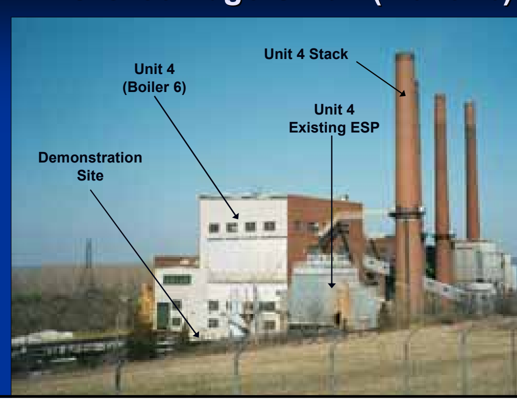
## Existing U.S. Coal-Fired EGUs
### 50-300 $MW_e$

- ~ 440 units not equipped with FGD or SCR
  - Represent ~ 60 GW of installed capacity
  - Greater than 80% are located east of the Mississippi River
  - Most have not announced plans to retrofit
- Difficult to retrofit for deep emission reductions
  - Large capital costs
  - Space limitations
- Increasingly vulnerable to retirement or fuel switching because of progressively more stringent environmental regulations
  - CAIR, CAMR, state regulations
- Need to commercialize technologies designed to meet the environmental compliance requirements of these units

## AES Greenidge Unit 4 (Boiler 6)

- Dresden, NY
- Commissioned in 1953
- 107 MWe (net) reheat unit
- Boiler:
  - Combustion Engineering tangentially-fired, balanced draft
  - 780,000 lb/h steam flow at 1465 psig and 1005 °F
- Fuel:
  - Eastern bituminous coal
  - Biomass (waste wood) – up to 10% heat input
- Current emission controls:
  - Overfire air (natural gas reburn not in use)
  - ESP
  - No FGD - mid-sulfur coal to meet permit limit of 3.8 lb/MMBtu

## AES Greenidge Unit 4 (Boiler 6)



## Multi-Pollutant Control Process

- Combustion modifications (outside DOE scope)
- Hybrid SNCR / SCR
  - Urea-based, in-furnace selective non-catalytic reduction
  - Single-bed, in-duct selective catalytic reduction
- Activated carbon injection
- Turbosorp® circulating fluidized bed dry scrubber
- Baghouse

## Greenidge Project Performance Targets

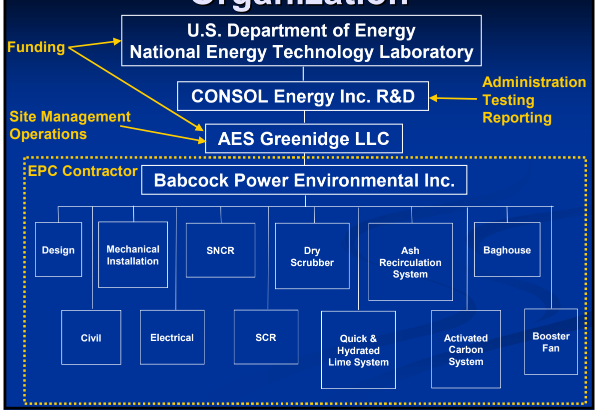
**Fuel: 2-4% sulfur bituminous coal, up to 10% biomass**

| Parameter | Goal |
|---|---|
| $NO_x$ | ≤ 0.10 lb/MMBtu (full load) |
| $SO_2$ | ≥ 95% removal |
| Hg | ≥ 90% removal |
| $SO_3$, HCl, HF | ≥ 95% removal |

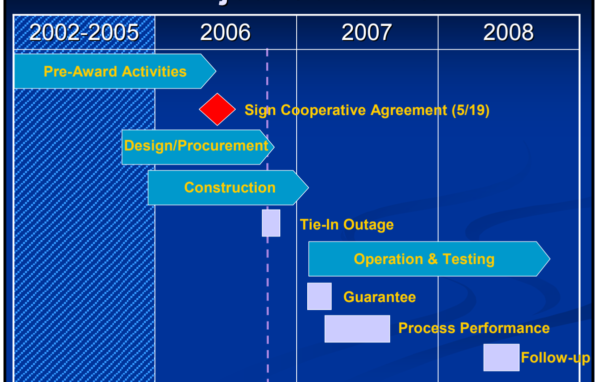
**Capital (EPC) Cost: ~ $330 / kW**

**Footprint: ~ 0.4 acre**

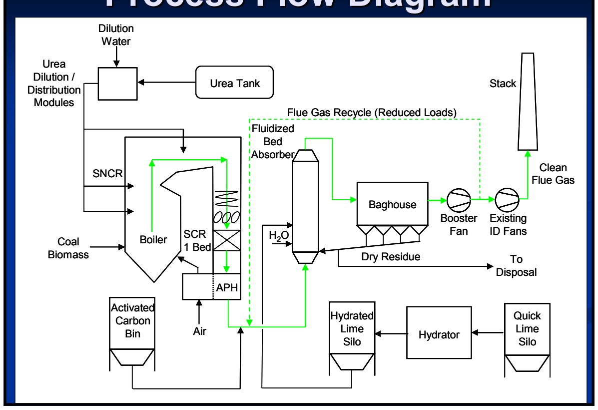
## Organization




## Project Schedule



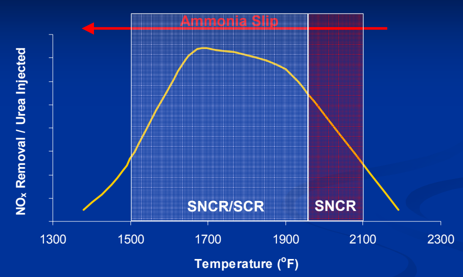

## Process Flow Diagram




## Hybrid $NO_x$ Control

- Combustion Modifications
  - Replace coal, combustion air, and overfire air nozzles
  - Improve fuel/air mixing, burner exit velocity, secondary airflow control, and upper furnace mixing; reduce CO
  - Reduce $NO_x$ to 0.25 lb/MMBtu
- SNCR
  - $CO(NH_2)_2 + 2\ NO + ½\ O_2 \rightarrow 2\ N_2 + CO_2 + 2\ H_2O$
  - Reduce $NO_x$ by ~ 42.5% (to 0.144 lb/MMBtu)
- SCR
  - $4\ NO + 4\ NH_3 + O_2 \rightarrow 4\ N_2 + 6\ H_2O$
  - $6\ NO_2 + 8\ NH_3 \rightarrow 7\ N_2 + 12\ H_2O$
  - Reduce $NO_x$ by > 30% (to ≤ 0.10 lb/MMBtu)

## SNCR for Hybrid System




- Greenidge Design:
  - 2 Levels of Wall Injectors (Higher Temperature)
  - 2 Multiple Nozzle Lances in Convective Pass (Lower Temperature)

## Delta Wing™ Static Mixers

- Homogeneous flue gas at catalyst face
  - $NO_x$ / $NH_3$ mole ratio ± 5% RMS deviation
  - Velocity ± 12% RMS deviation
  - Temperature ± 30 °F
- Minimize $NH_3$ slip
- Maintain mixing at reduced load operation
- Maintain ash entrainment and distribution

## Single-Bed, In-Duct SCR

**Bed Depth**

~ 1.3 m

**$SO_2 \rightarrow SO_3$**

< 1.0 %

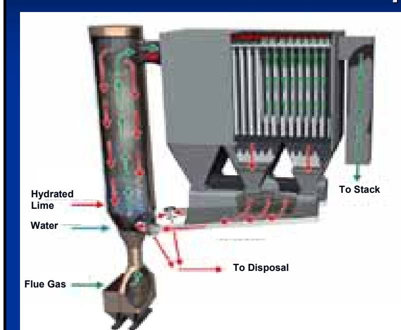
**$NH_3$ Slip**

< 2 ppmv

**$NO_x$ Removal**

> 30%

## Circulating Fluidized Bed Dry Scrubber Process Concept




- Completely dry
- Separate control of reagent, water, and recycled solid injection
- High solids recirculation
- Applicable to high-sulfur coals
- 15-25% lower reagent consumption than SDA
- Low capital and maintenance costs relative to other FGD technologies

## Circulating Fluidized Bed Dry Scrubber Chemistry

$$Ca(OH)_2 + SO_2 \leftrightarrow CaSO_3 \cdot ½\, H_2O + ½\, H_2O$$

$$Ca(OH)_2 + SO_3 \leftrightarrow CaSO_4 \cdot ½\, H_2O + ½\, H_2O$$

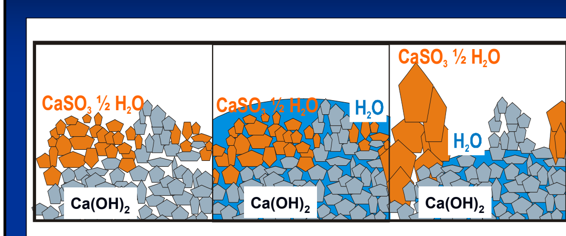
$$CaSO_3 \cdot ½\, H_2O + ½\, O_2 \leftrightarrow CaSO_4 \cdot ½\, H_2O$$

$$Ca(OH)_2 + 2\, HCl \leftrightarrow CaCl_2 + 2\, H_2O$$

$$Ca(OH)_2 + 2\, HF \leftrightarrow CaF_2 + 2\, H_2O$$

$$Ca(OH)_2 + CO_2 \leftrightarrow CaCO_3 + H_2O$$

## Reactivation of Recycled Reagent




Reaction after first pass

Water added to surface during recirculation

Sulfite crystal forms, exposing fresh surfaces

## Turbosorp® System at AES Greenidge

- On-site lime hydration system
- 8-compartment pulse jet fabric filter
- Projected Ca/S of 1.5-1.6

## Mercury Control

- Expect ≥ 90% removal with low carbon injection rate
  - Similarity to SCR / SDA / FF with bituminous coal
    - Field sampling shows 90% Hg removal often achieved with no ACI
  - Projected activated carbon requirement: 0 – 3.5 lb/MMacf
- SCR catalyst
  - Oxidize $Hg^0$ to $Hg^{2+}$
- Activated carbon injection
  - Adsorb $Hg^0$ and $Hg^{2+}$
- Circulating fluidized bed dry scrubber / baghouse
  - Reduce temperature (~ 170 °F)
  - Facilitate contact between Hg and carbon, fly ash, $Ca(OH)_2$
    - Filter caking
    - Recirculation = high sorbent residence time

## Challenges / Uncertainties

- Performance with 2-4% sulfur eastern bituminous coal
  - Ammonium bisulfate formation / fouling
  - $SO_2$ capture and required Ca/S ratio
- Hg removal performance
  - Extent of $Hg^0$ oxidation at high space velocities in single-bed catalyst
  - Carbon injection requirements
- Control of integrated system, especially during load swings / cycling
  - Effect of $NH_3$ slip on unit operability
- Effect of biomass co-firing

## Concluding Thoughts

- Innovative approach to multi-pollutant control that provides a low-capital-cost retrofit option for smaller coal-fired units
  - Emission reduction targets:
    (2-4% sulfur coal, up to 10% biomass)
    - $NO_x$ to ≤ 0.10 lb/MMBtu
    - $SO_2$ and acid gases by > 95%
    - Hg by > 90%
    - Improved control of fine particulate matter
  - Capital cost: ~ $330/kW (delivered + erected) for 100 MW unit
  - Footprint: ~ 0.4 acres for 100 MW unit
  - Operational flexibility
- Actual performance data will be available soon
  - System fully operational by beginning of 2007
  - Initial performance results in early-to-mid 2007
  - Long-term performance results and actual operating costs in mid-2008

# APPENDIX B

## *AES Greenidge Multi-Pollutant Control Project*

Presented at the December Luncheon of the Air & Waste Management Association's Genesee Finger Lakes Chapter, Rochester, NY, December 13, 2006.

## AES Greenidge Multi-Pollutant Control Project


**Douglas J. Roll, P.E., and William B. Rady**
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Air & Waste Management Luncheon Meeting
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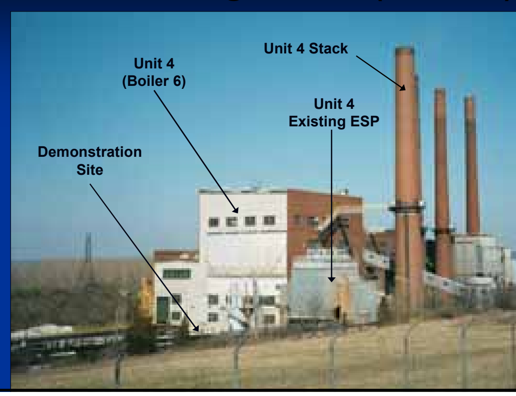


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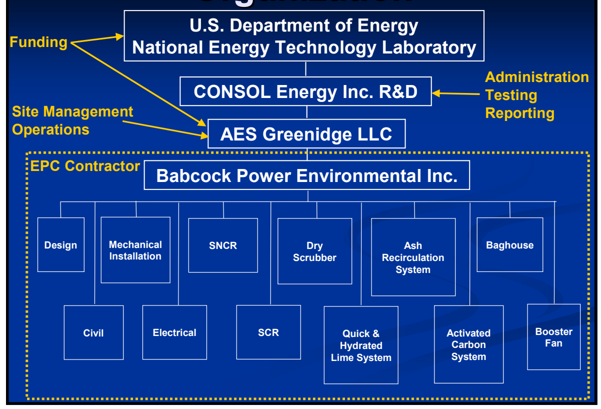


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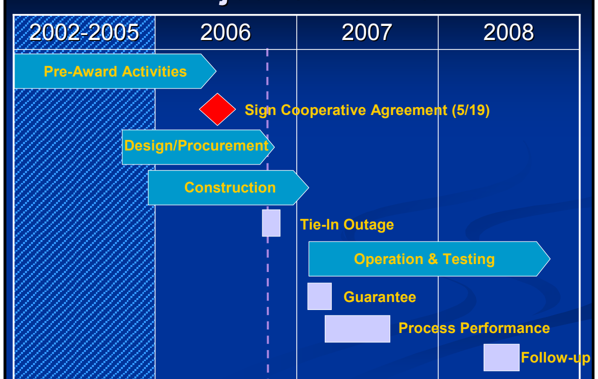


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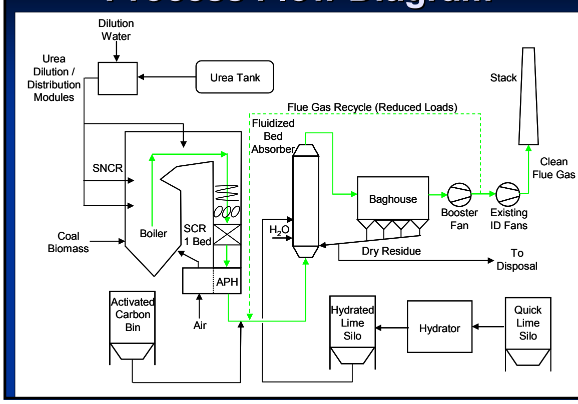


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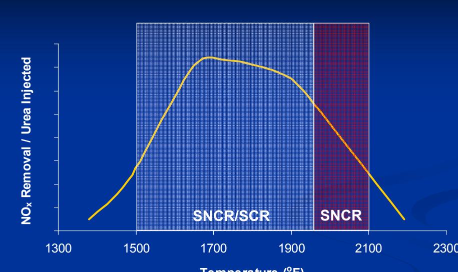


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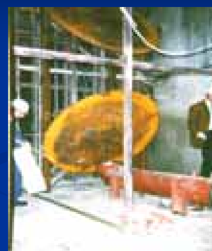

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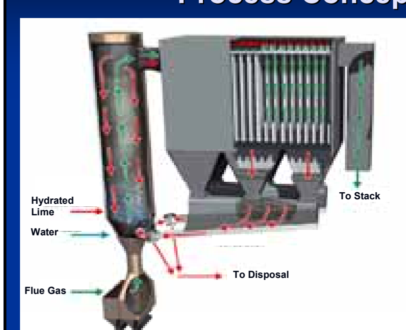


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