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Project Summary

Cost of Selective Catalytic Reduction (SCR) Application for NO_X Control on Coal-fired Boilers

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The report provides a methodology for estimating budgetary costs associated with retrofit applications of selective catalytic reduction (SCR) technology on coal-fired boilers. SCR is a postcombustion nitrogen oxides (NO_X) control technology capable of providing NO_X reductions >90%. With SCR, NO_X reductions are achieved by injecting ammonia into the flue gas, which then passes through layers of catalyst in a reactor. The ammonia and NO_X react on the surface of the catalyst, forming nitrogen and water. In the U.S., SCR has been applied mainly to electrical utility boilers firing coal and natural gas and ranging in capacity from 25 to 800 MW.

The costing methodology presented in the report is applicable to SCR retrofits on coal-fired boilers ranging in capacity from 100 to about 850 MW and with design efficiencies of 80-95% NO_X removal. The cost equations and variables used in the methodology are based on information obtained from SCR system suppliers and reflect experience gained from >200 SCR applications. Note, however, that the budgetary cost estimates for typical SCR applications that this methodology provides cannot replace the detailed site-specific engineering cost studies or cost quotations that are developed by SCR system suppliers.

This Project Summary was developed by the National Risk Management Research Laboratory's Air Pollution Prevention and Control Division, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Background

Selective catalytic reduction (SCR) is a postcombustion nitrogen oxides (NO_X) control technology capable of providing NO_X reductions >90%. With SCR, NO_X reductions are achieved by injecting ammonia into the flue gas, which then passes through layers of catalyst in a reactor. The ammonia and NO_X react on the surface of the catalyst, forming molecular nitrogen (N_2) and water. In the U.S., SCR has been applied mainly to electric utility boilers firing coal and natural gas.

The report provides algorithms for estimating costs and performance of generic SCR retrofit applications on coal-fired boilers. Specifically, the algorithms are applicable to SCR systems with design efficiencies of 80-95% NO_X removal that can operate on coal-fired boilers ranging in size from approximately 100 to 850 MW. The cost equations and variables are based on industrial experience gained from >200 SCR applications. Note that the algorithms presented in this work are not meant to replace the detailed engineering studies or cost quotations that are developed by system suppliers, nor should these algorithms be used to determine detailed site-specific costs for retrofit SCR applications.

The Costing Algorithms

SCR budgetary costing algorithms for capital as well as fixed and variable operating and maintenance (O&M) costs (in January 2000 dollars) are given below.

The capital cost, D ($/kW), of an SCR retrofit application is estimated using Equation (1):

$$D = 75 \{300{,}000\ Z/A\}^{0.35} \quad (1)$$

where:

$$Z = [(B/1.5)^{0.05}\ (C/100)^{0.4}]$$

and

D = capital cost ($/kW)
75 = capital cost ($/kW) associated with a typical SCR retrofit on a 300,000 kW coal-fired unit
300,000 = reference to a 300,000 kW baseline unit (basis for the economy-of-scale adjustment in the equation)
B = NO_X (lb/10^6 Btu) at the inlet of the SCR reactor; range of approximately 0.15-2.5 lb/10^6 Btu
0.05 = exponent for inlet NO_X concentration
C = NO_X removal efficiency (%); range of 80-95%
0.4 = exponent for NO_X removal efficiency
A = plant capacity (kW); range of approximately 100,000-850,000 kW
0.35 = exponent for an economy-of-scale adjustment factor (scaled from a 300,000 kW unit)

The complexity of an SCR system design is dependent on the plant layout. For example, a relatively constrained plant layout may involve a more difficult SCR system design compared to a relatively unconstrained layout and, therefore, may require more ductwork and air heater modifications. In contrast, a relatively unconstrained layout may not need air heater modifications and more than the typical amount of ductwork. To account for varying levels of design complexity, a degree of difficulty is associated with an SCR retrofit application. In this context, the average degree of difficulty is assigned to a retrofit where the SCR installation is relatively simple (i.e., the facility has adequate space for the SCR system). Equation (1) assumes this average degree of difficulty.

The fixed O&M cost, E ($/yr), is assumed to be 0.66% of the capital cost and is estimated using Equation (2):

$$E = D \bullet A \bullet C \quad (2)$$

where:

E = fixed O&M cost ($/yr)
D = capital cost ($/kW) from Equation (1)
A = plant capacity (kW); range of approximately 100,000-850,000 kW
C = a constant; 0.0066 yr^{-1}

The variable O&M cost, F ($/yr), is estimated using Equation (3):

$$F = G \{225 \bullet [0.37B \bullet H \bullet (C/100) \bullet (8760/2000)] \bullet 1.005 \bullet 1.05 + 0.025 \bullet D \bullet A \bullet Z + 1.45 \bullet A\} \quad (3)$$

where:

F = variable O&M cost ($/yr)
G = annual capacity factor (expressed as a fraction)
B = inlet NO_X (lb/10^6 Btu); range of 0.15-2.5 lb/10^6 Btu
H = heat input (10^6 Btu/hr)
C = NO_X removal efficiency (%); range of 80-95%
D = capital cost ($/kW)
A = plant capacity (kW); range of approximately 100,000-850,000 kW

Validation of the Costing Algorithms

The costing methodology presented above was derived from information provided by SCR system suppliers and is deemed valid for typical coal-fired SCR retrofit applications for NO_X removal efficiencies in the range of 80-95%. Note, however, that this methodology is intended and valid for developing budgetary cost estimates and assumes typical installations. Therefore, the methodology should not be expected to account for reported costs of each site-specific SCR retrofit application.

In a 1998 study conducted for Northeast States for Coordinated Air Use Management (NESCAUM) and Mid-Atlantic Regional Air Management Association (MARAMA), the capital cost for SCR retrofit on dry-bottom wall- and tangentially fired boilers to achieve 85% NO_X reduction was estimated to be 70-90 $/kW. Similarly, the study estimated that the capital cost of SCR retrofits to achieve 90% NO_X reduction from wet-bottom boilers would also be 70-90 $/kW. Note that these estimates were based on 330 MW units. In comparison, the costing methodology results in an estimate of approximately 70 $/kW for similar units.

Recent literature reflects a range of 55-140 $/kW as being typical of site-specific retrofit SCR capital costs for all types of utility boilers. By comparison, the costing methodology estimates a capital cost of approximately 50-110 $/kW to achieve 85-95% NO_X removal efficiency.

The NESCAUM/MARAMA report estimated a combined fixed and variable O&M cost of reducing NO_X by 70-80% for a 330 MW dry-bottom boiler at approximately $1.1 million/yr and approximately $2.8 million/yr for a similar-sized wet-bottom boiler. The costing methodology estimates the combined fixed and variable O&M costs for all boiler types to be about $1.0 to 1.7 million/yr for 85% NO_X removal. In another economic analysis of SCR retrofits on 300 and 500 MW boilers to reduce NO_X by 80-85%, combined O&M costs were estimated to be $1.6-3.2 million/yr.

Based on the above comparisons, the capital and O&M cost estimates derived from applying this methodology are deemed reasonably accurate and fall well within the ranges reported elsewhere. Actual cost reported from site-specific SCR retrofit applications, as well as individual facility engineering studies, would more accurately reflect the circumstances of individual facilities. As a result, it is also reasonable to expect that reported actual costs may not always conform to budgetary cost estimates that have been designed around typical installations. While the methodology has been shown to consistently estimate costs that fit well with other reported actual and estimated costs, occasionally it can be expected that there will be data with higher or lower costs.

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The complete report, entitled "Cost of Selective Catalytic Reduction (SCR) Application for NO_x Control on Coal-Fired Boilers," will be available at http://www.epa.gov/ORD/NRMRL/Pubs/600R01087/600R01087all.pdf. It will also be available from NTIS (Order No. PB2002-100499; Cost: $23.00, subject to change) at the following address:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161-0001
Telephone: (703) 605-6000
(800) 553-6847 (U.S. only)

The EPA Project Officer can be contacted at:

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