Andover Technology Partners 978-683-9599
Consulting to the Air Pollution Control Industry

ENGINEERING AND ECONOMIC FACTORS AFFECTING THE INSTALLATION OF CONTROL TECHNOLOGIES

An update

By

James E. Staudt, PhD

Andover Technology Partners
112 Tucker Farm Road
North Andover, MA 01845
(978) 683-9599

www.AndoverTechnology.com

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List of Acronyms

AC	Activated carbon
ACI	Activated carbon injection
CAAA	Clean Air Act Amendments
CDS	Circulating Dry Scrubber
COHPAC	Compact Hybrid Particle Collection
CSAPR	Cross State Air Pollution Rule
DCS	Distributed control system
DSI	Dry Sorbent Injection
ESP	Electrostatic precipitator
FF	Fabric filter
FGD	Flue gas desulfurization
GW_e	Gigawatt (electric)
HCl	Hydrochloric acid
Hg	Mercury
IPM	Integrated Planning Model
LSD	Lime spray dryer
LSFO	Limestone forced oxidation
MATS	Mercury and Air Toxics Standards
MEL	Magnesium enhanced lime
MW_e	Megawatt (electric)
NAAQS	National Ambient Air Quality Standards
NACBE	National Association of Construction Boilermaker Employers
NEEDS	National Electric Energy Data System
PAC	Powdered Activated Carbon
PIPP	Presque Isle Power Plant
PJFF	Pulsejet fabric filter
PLC	Programmable logic controller
PM	Particle Matter
PPS	polyphenylene sulfide
SBS	Sodium bisulfate
SBC	Sodium bicarbonate
SCR	Selective catalytic reduction
SDA	Spray Dryer Absorber
SIP	State Implementation Plan
TOXECON	Toxic Emission Control System

Executive Summary

This report is intended to provide an update to the information in the 2002 report ENGINEERING AND ECONOMIC FACTORS AFFECTING THE INSTALLATION OF CONTROL TECHNOLOGIES FOR MULTIPOLLUTANT STRATEGIES (EPA-600/R-02/073, released October 2002, which will be referred to as the 2002 Report) that was examined the resources needed to install pollution control technologies in response to various policies. That report focused on the resources necessary for NOx, SO2 and mercury control from coal-fired utility boilers. Since that time,

- The utility industry underwent a retrofit program that has resulted in about 60% of the coal capacity to be equipped with scrubbers and about half with post-combustion NOx controls (like selective catalytic reduction technology, or SCR), yielding important real world data,
- There have been technological advancements in air pollution control in the intervening nine years, especially in the area of activated carbon injection and dry sorbent injection, and
- The US EPA has finalized rules that will likely cause the installation of additional controls, such as fabric filters.

In updating the 2002 Report, this report focused on the resources needed for installation of scrubbers, selective catalytic reduction systems (SCR), activated carbon injection (ACI) systems, dry sorbent injection systems (DSI), and fabric filters. The experience with installing SCRs and scrubbers in response to the NOx SIP Call, the Clean Air Interstate Rule (CAIR) and other requirements provided useful data to compare against the findings of the 2002 Report. With regard to these technologies,

- Although construction materials were available as expected, prices generally increased from 2003 to 2008 as a result of high global demand, especially from China.
- Experience showed that the time to complete FGD and SCR projects was largely consistent with the findings of the 2002 Report, but in a few cases was longer than stated in the 2002 Report. This was, at least in part, due to a much greater than expected retrofit effort on the part of the utilities that caused lead times for key equipment components to temporarily become longer than normal. Industry adapted and found alternatives, and recent experience with these controls indicates that installation time for FGD and SCR is consistent with the 2002 Report, and installation time for DSI, ACI, and fabric filters is considerably lower than for SCR and FGD.
- Using historical boilermaker employment data, actual labor demands for SCR and scrubbers were determined to be greater than projected in the 2002 Report. This is significant because when CAIR was finalized, labor was envisioned to be a limiting factor in the ability of utilities to install equipment in response to the CAIR. However, this study found that labor supply increased as demand increased. Table E-1 summarizes the estimated boilermaker and other labor needs. These numbers should be regarded as approximate, with actual demand for any given project differing based upon the particular characteristics of the project.
- Despite the above factors, many more projects were completed in response to CAIR than originally anticipated because

- Utilities started their engineering and procurement efforts prior to the finalization of the rule
- Utilities found new suppliers of equipment or adapted their designs to utilize less costly materials in response to increased material prices
- Availability of craft labor, boilermakers in particular, was not as limiting as previously envisioned

ACI and DSI systems were also examined, and review of these technologies determined that

- Installation of these systems is far less resource intensive than SCRs or scrubbers and there is no specialized equipment or materials that are likely to pose bottlenecks.
- These systems can be installed in under 18 months, from early design to completion of commissioning.
- Reagent, which is needed in an ongoing basis to remove pollutants, is available in sufficient quantities to meet expected demand. New activated carbon (AC) plants have been built to meet the needs of this market, and more are already approved for construction as demand ramps up. DSI reagent is already plentiful, as the material is already mined for other applications.

Fabric filters (FFs) are examined in the final chapter of this report. Unlike ACI and DSI systems, FFs are somewhat more resource intensive, but generally not as resource intensive as SCRs and scrubbers. In this chapter it was determined that

- The time period to install a fabric filter, once an order was placed, was roughly two years. This was consistently shown with both data from DOE programs (such as the program at the Presque Isle Power Plant) and data from technology suppliers, as described further in this report. Preliminary engineering work done prior to placing the order might add a few more months.
- Special equipment that may be needed are large fans and motors, and lead times might increase for these items, but probably not to the extent that was experienced with large recycle pumps, since fans are used in a wider range of applications than the special recycle pumps used for wet scrubbers.
- Demand for filter bags is anticipated to increase; however, additional production capacity may not be necessary depending upon the extent of utility advance planning. If needed, supply can be increased well within the anticipated time period of the rule.

Table E-1. Approximate labor demand generated from technology installations, in manhours per MW of capacity

	SCR	Wet Scrubber	Dry Scrubber	ACI	DSI	Fabric Filter
Boilermakers	440	545	*	*	*	375
Other Labor	660	1,885	*	*	*	405
Total	1,100	2,430	1,725	9.6	55	780

** Only total manhour data was available.*

Note – These estimates of manhour should be regarded as approximate and useful for making order of magnitude estimates of labor resource demands. Because of the site-specific nature of various retrofit projects, these estimates are likely to differ somewhat from estimates developed using other data sources.

Chapter 1
Background and Purpose

Background

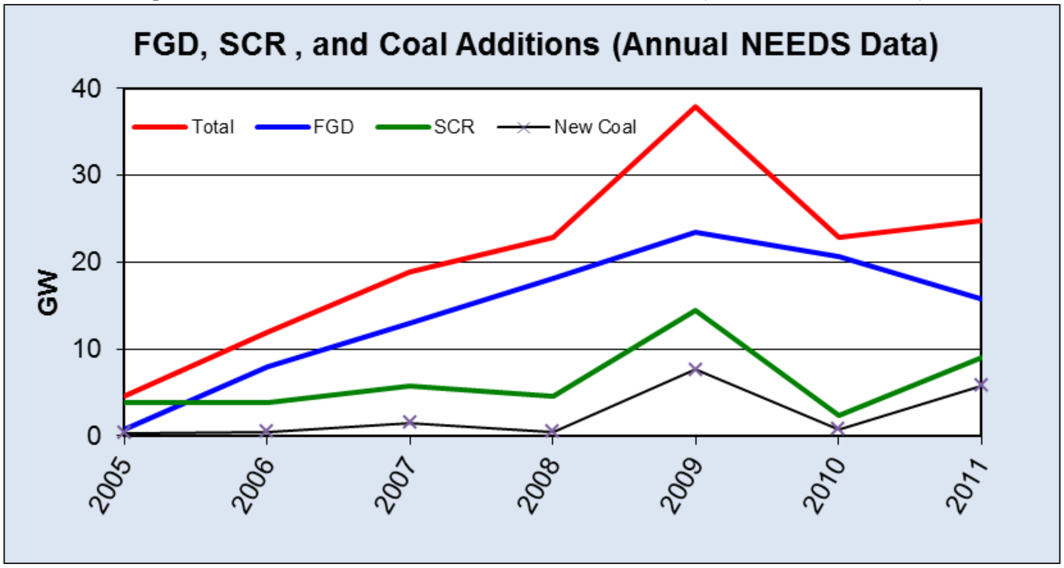
US EPA has finalized the Utility Mercury and Air Toxics Standards (MATS) and the Cross State Air Pollution Rule (CSAPR). The MATS establishes limitations on coal power plant air toxics, such as mercury, metals (total particle matter), and acid gases (HCl). The CSAPR establishes state budgets for NOx and SO2 in order to mitigate the effects of transport of ground level ozone and fine particle matter from upwind sources. As a result of these rules, coal fired electric boilers are expected to install pollution controls, which require the use of resources such as labor, materials, equipment, and reagents. Installation of controls will also require time. This report will examine the resources and the time needed to install these controls.

Purpose

This report is intended to provide an update to the information in the 2002 report ENGINEERING AND ECONOMIC FACTORS AFFECTING THE INSTALLATION OF CONTROL TECHNOLOGIES FOR MULTIPOLLUTANT STRATEGIES (EPA-600/R-02/073, released October 2002, which will be referred to as the 2002 Report) that was examined the resources needed to meet the requirements of the Clear Skies Act that was proposed in 2002. Although the Clear Skies Act was not passed, the information in the report was useful in the analysis of the Clean Air Interstate Rule (CAIR). The primary goal of this report is to provide an update of information in the 2002 report with special attention given to information that is important to understanding the resource needs and resource availability for those technologies necessary for MATS and CSAPR.

In the time since the 2002 Report was issued, EPA promulgated the Clean Air Interstate Rule (CAIR), which established NOx and SO2 emissions requirements with initial compliance dates of 2009 (NOx) and 2010 (SO2), and additional requirements in 2015. During the period 2005 through 2011, in response to CAIR and other clean air programs, the electric utility industry embarked on an unprecedented retrofit program, installing nearly 100 GW of wet and dry scrubbers and about 40 GW of SCR systems on coal-fired power boilers. This is shown in Figure 1-1, which is a plot of SCR and scrubber retrofits and new coal capacity (in MW) for the years 2005-2011 taken from the National Electric Energy Data System (NEEDS v4.10PTox). During this time the industry also installed about 17 GW of new coal-fired capacity. As a result of this effort to reduce emissions of NOx and SO2 pollutants, the industry also made progress in the control of hazardous air pollutants (HAPs) because the controls installed for NOx and SO2 emissions can reduce emissions of HAPs due to the co-benefit effects of some types of controls. The retrofit effort for CAIR has reduced the additional controls that would otherwise be necessary under the proposed MATS or CSAPR.

Figure 1-1. FGD, SCR and New Coal Generation (NEEDS v4.10PTox).

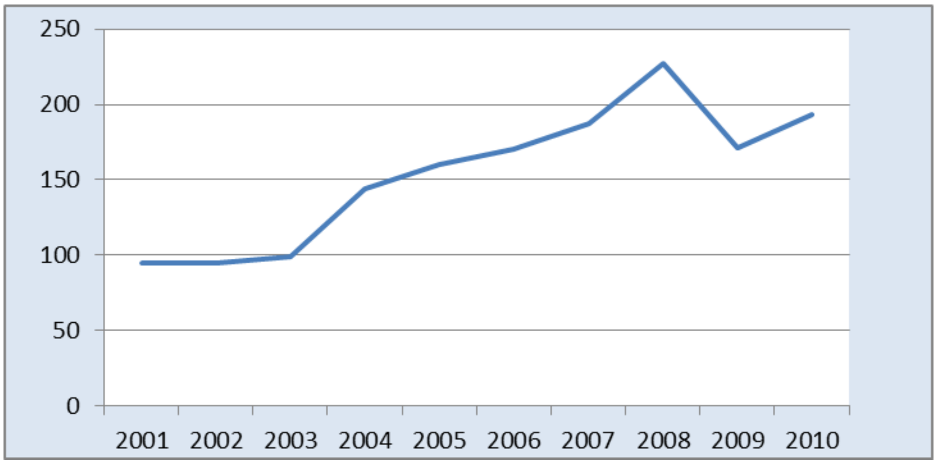


This report will provide useful information on the resources necessary to meet the proposed MATS and the CSAPR and will provide updated information on the resources necessary for the technologies discussed in the 2002 Report. This report will also address technologies not included in that report, but expected to be important in utility boiler emissions control for the proposed MATS and the CSAPR. In general, resources necessary for any air pollution control technology include the following:

- Construction materials, such as steel, concrete or other materials used for the structure and ductwork, foundations, and major components
- Specialty fabricators – special fabrication of components from steel or concrete, examples include concrete chimneys, large forgings or large fabricated steel components
- Engineered equipment, such as large pumps, fans, motors, etc.
- Specialty materials, such as catalyst, filter bags, etc.
- Reagents, including limestone, lime, Trona, activated carbon, etc.
- Labor, especially specialized construction labor, such as boilermakers

Construction materials are traded globally. During the period that utilities installed equipment in response to the CAIR, there was a construction commodity boom driven largely by high demand for these materials in Asia. As a result, the price of these materials experienced a steep rise that trended well into 2008. Figure 1-2 shows the producer price index (PPI) for hot rolled steel bars, plates and structural shapes. Prices more than doubled in the time from 2003 to 2008. The volatility of construction commodity prices is therefore something that becomes important for companies in managing cost. In fact, as will be discussed in later sections of this report, it can cause companies to modify designs to incorporate other materials.

Figure 1-2. Producer Price Index for Hot Rolled Steel Bars, Plates and Structural Shapes
Source: Bureau of Labor Statistics



Because the 2002 Report determined that availability of construction commodities was not a concern (although cost could become a concern depending upon global supply and demand), examination of the availability of construction commodities will not be explored in this report.

In addition to the resources needed to install this equipment, this study will examine the time necessary to install this equipment, to include engineering, procurement, installation, and startup, and commissioning, with these described as follows:

- Engineering – both preliminary and detailed engineering. Normally, there is some engineering performed prior to placing an order with a pollution control vendor. There is also detailed engineering performed after the order is placed to develop detailed specifications for procurement.
- Procurement – ordering and taking delivery of ordered equipment on site
- Installation – installation of delivered equipment, to include related construction activities
- Startup – pre-commissioning startup of components and subsystems performed prior to final commissioning and performance testing of the full air pollution control system
- Final Commissioning – start-up of the control system and completion of performance testing

The remaining chapters of this report will be organized in the following manner:

Chapter 2- SCR and FGD - update from 2002 study

Resource needs and availability are updated in this chapter based upon experience with CAIR. Particular attention is given to:

- Time needed to install equipment
- Equipment needed
- Labor requirement - look back at actual labor statistics and project data to provide more reliable estimates for SCR, wet FGD and dry FGD

Chapter 3 – Activated Carbon Injection (ACI) and Dry Sorbent Injection (DSI)

DSI was not included in previous study. The study will pay particular attention to:

- Time, equipment and labor
- Resource needs and availability, with particular attention given to reagents (AC and trona)

Chapter 4 - Fabric Filter (FF), or Baghouse systems

Fabric filters were not included in the previous study.

- Time, equipment and labor resources are all examined in this study

Chapter 2

Scrubber and SCR Update

In this chapter, the resource requirements to retrofit flue gas desulfurization (FGD) systems to remove SO_2 and Selective Catalytic Reduction (SCR) systems to reduce NOx will be updated from the 2002 Report.

Like the 2002 Report, the chapter focuses on the resources and time necessary for typical scrubber or SCR retrofit.

A review of installation experience

With the benefit of the experience gained from implementation of SCR and FGD systems installed in response to the NOx SIP Call and CAIR, it is possible to reexamine the information in the 2002 Report. This will include: 1) installation time, 2) equipment availability, and 3) labor availability.

Installation Time

The 2002 Report determined that for a single boiler, single absorber system, a wet FGD system could be installed in roughly 27 months. Multiple boiler or multiple absorber systems or systems with difficult site constraints would require more time. Constellation has reported that the new air quality control system (AQCS), which included fabric filter, sorbent injection, and wet scrubber, for the two 640 MW Brandon Shores boilers in Baltimore took 26 months from groundbreaking to completion of construction. [1] The construction period was preceded by roughly a year of engineering/procurement activities, and there were additional months needed for commissioning. The timeline is summarized below:

- 2006-2007: Studies on Control System Technology and initial engineering
- June 2007:Groundbreaking on AQCS
- September 2009: Construction complete
- November 2009: Unit 1 AQCS in service
- February 2010: Unit 2 AQCS in service
- July 2010: Wastewater system functional

Some companies that installed wet FGD systems in response to CAIR reported longer installation times, up to about five years, especially if preliminary engineering is included and if the FGD is installed contemporaneously with an SCR.[2] Longer than anticipated time periods for scrubber projects may have been the result of the greater than expected response of the utility industry, which did temporarily result in extended delivery times for certain key equipment as will be discussed below and also caused some companies to manage large, multi-scrubber installation programs.

The industry response to CAIR exceeded what had been believed to be possible when CAIR was issued. In the Regulatory Impact Analysis performed for CAIR, EPA stated that it expected retrofits of roughly 90,000 MW of new FGD systems and 37,000 MW of new SCR systems by 2020. [3] An additional 22,700 MW of SCR and FGD was expected for new coal-fired power plants. Of this US EPA expected 36,000 MW of FGD and 15,000 MW of SCR to be completed by 2010 for Phase I. It was anticipated that available labor, especially boilermakers, and available time would be the limiting factors in determining the amount of scrubbers that would be installed. [4] However, in 2007 EPA revised its estimate of the scrubber capacity to be installed in response to CAIR based upon announced projects and projected more scrubbers to be installed by 2010 than it had previously anticipated to be installed by 2015. In 2007, factoring in projects that had been announced and committed to, it appeared that at least 55,000 MW of new FGD capacity would be in operation by 2009 and estimated about 80,000 MW of total new FGD by 2010. This compares to the late 2005 estimate of about 36,000 MW by 2010 and 72,000 MW by 2015.[5] The effect of this greater than expected response was that the demand for key components (such as large recycle pumps) or specially fabricated equipment (such as chimneys) was increased more than anticipated. As a result, lead times for delivery of these items increased, which had an impact on schedules. Despite the longer time period experienced for some projects, the utility industry managed to execute more projects than anticipated for the following reasons.

1. Some utilities placed orders earlier than EPA had originally anticipated at the time CAIR was finalized, providing more time
2. Companies managed the retrofit programs and system designs to
    a. more efficiently utilize resources and
    b. respond to changing cost or availability of equipment or materials
3. Labor supply, originally expected to be the limiting factor for retrofits, was not as constraining as anticipated

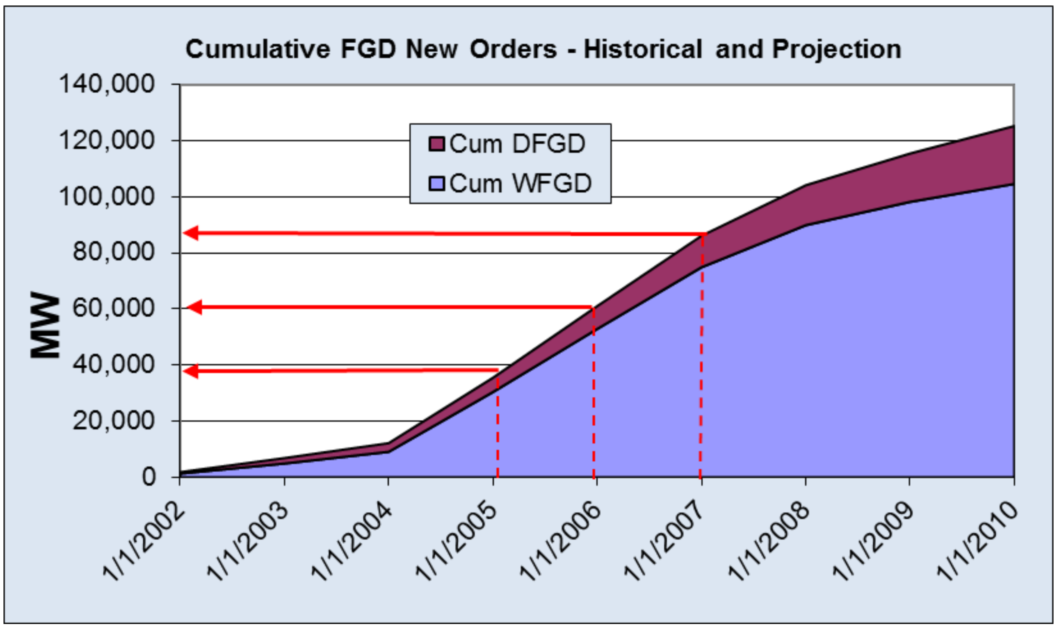
These are examined further in the following paragraphs.

Advance planning and early orders

Scrubbers typically take longer to design and install than SCRs. Because of the process EPA uses to propose a rule and receive comments, many aspects of the final CAIR rule were anticipated. Many utilities, in anticipation of the final CAIR rule, privately commenced engineering activities and began ordering scrubbers. Figure 2-1 is a plot of data from the Institute of Clean Air Companies' 2006 Annual Market Survey. According to the Institute of Clean Air Companies' 2006 Annual Market Survey nearly

40,000 MW of scrubbers – mostly wet FGD (WFGD) - had been ordered prior to January 2005, before CAIR was finalized in March 2005, and nearly 60,000 MW of scrubbers were ordered by the end of 2005, within months after CAIR was finalized. By end of 2006 most of the scrubbers that would be ordered during the period of CAIR phase 1 were under contract. Because there is a significant amount of planning performed prior to placing the order with the equipment supplier, it is apparent that many utilities started planning for CAIR well in advance of it being finalized and had already performed much of their preliminary engineering and procurement activities prior to finalization of CAIR in March 2005.

Figure 2-1. Cumulative FGD New Orders [6]



Managing Resources and Changing Designs

In anticipation of installing multiple scrubbers and the increased demand for recycle pumps, large motors and other special equipment needed for scrubbers, many utilities standardized around one or two scrubber designs for all of their plants. For example, Duke Power Carolinas standardized around Alstom's Spray Tower design for all of their wet scrubbers[7] and Southern Company standardized on two designs - Advatech and the Chiyoda Process - for their wet scrubbers[8]. In doing so, these companies were able to have more consistency in management of their multi-scrubber projects, standardization of procurement methods and components, and could commit to manufacturers and specialty fabricators well in advance for supply of critical components that would require longer lead times for delivery. This planning in advance was important because lead times for several critical components increased substantially. For example, one report stated that lead times for large, rubber-lined recycle pumps increased from about 26 weeks in 2003 to about 2 years in 2006.[9] This was no-doubt a result of the large number of FGD orders placed in the months immediately prior to or shortly after the finalization of CAIR.

As a result of the high demand for some equipment, some companies started considering alternative sources for these key components as the sources of supply expanded beyond the more familiar suppliers in the US. For example, although Weir and GIW are the best known suppliers of large recycle pumps used in US scrubbers, there are overseas suppliers as well. European suppliers, some being subsidiaries of US pump suppliers, have supplied their recycle pumps to US projects, and China has developed the capacity to manufacture large recycle pumps, including replicas of some of the larger pumps made by the major US pump suppliers. [10]

Changing designs in response to changing material prices

Wet scrubbers subject materials to a corrosive and abrasive environment. This includes the slurry recirculation piping, the spray headers, the absorber vessels and the chimney liners. There are various options for materials, including rubber or tile coatings, nickel based alloys or fiberglass reinforced plastic (FRP). The two materials that are most often used for internal scrubber parts are nickel based alloys and FRP. Prior to 2006 nickel based alloys were the preferred material of construction for parts of the scrubber that are exposed to high levels of corrosion. During the 1990's the price of nickel was in the \$3-\$4 per pound range; however, by 2006 prices rose to \$15/lb and reached \$25/lb in 2007. This was partly due to increased demand in the US, but also due to increased global demand for metals, particularly in China. As a result, the market for scrubber materials for US projects shifted from nickel based alloys to FRP. In the period 2004-2005, only 8 scrubber chimneys used FRP liners. In 2007 49 chimneys used FRP liners and in 2008 at least 39 new chimneys were installed with FRP liners. But, the use of FRP was not limited to chimney liners. In 2008, of the \$500 million spent worldwide on FRP scrubber components, about \$120 million was on spray headers, \$120 million on recirculation piping, just over \$100 million was spent on vessels, tanks and piping, and about \$160 million on chimney liners. [11] In fact, in 2007 the two largest fiberglass scrubber vessels in the world were built at Georgia Power's Plant Bowen. Each Plant Bowen FRP vessel was 119 feet in diameter and 54.5 feet tall and was spun in place.[12]

Labor

Labor is necessary in terms of engineers and managers that design and specify the equipment, procure it, and supervise the installation, and in terms of skilled laborers that install the equipment to the boiler. A critical labor component is the supply of boilermakers that have skills uniquely suited to the power industry. Many other trades can be drawn from the broader construction industry. For this reason boilermakers are generally viewed to be the most limiting skilled labor component in these retrofits. The demand for boilermakers also provides a good proxy for the demand for other skilled labor trades drawn from the broader construction industry. The 2002 Report stated that a 500 MW_e unit FGD system retrofit requires 380,000 man-hours, or approximately 200 person-years, of which 20 percent, or 72,000 man-hours, are dedicated to engineering and project management, and roughly 40 percent of man-hours are for boilermakers. The balance of the construction labor needs is supplied from other construction trades. This equates to roughly 304 boilermaker manhours per MW. For SCRs, the 2002 Report stated that total construction labor for an SCR system of 500 MWe is in the range of 333,000 to 350,000 man-hours with typically about 40-50 percent of the labor is for boilermakers. This would equate to roughly 307 boilermakers per MW installed. These estimates in the 2002 Report were based upon available data from technology suppliers, which likely were the result of recent projects they may have performed. Since these manhour estimates were from the technology suppliers, they may not have included the full scope of supply, especially for balance of plant labor. Total manhour requirements will depend upon the total scope of supply for the scrubber, which may include several significant items to support the scrubber, such as reagent preparation systems or water treatment.

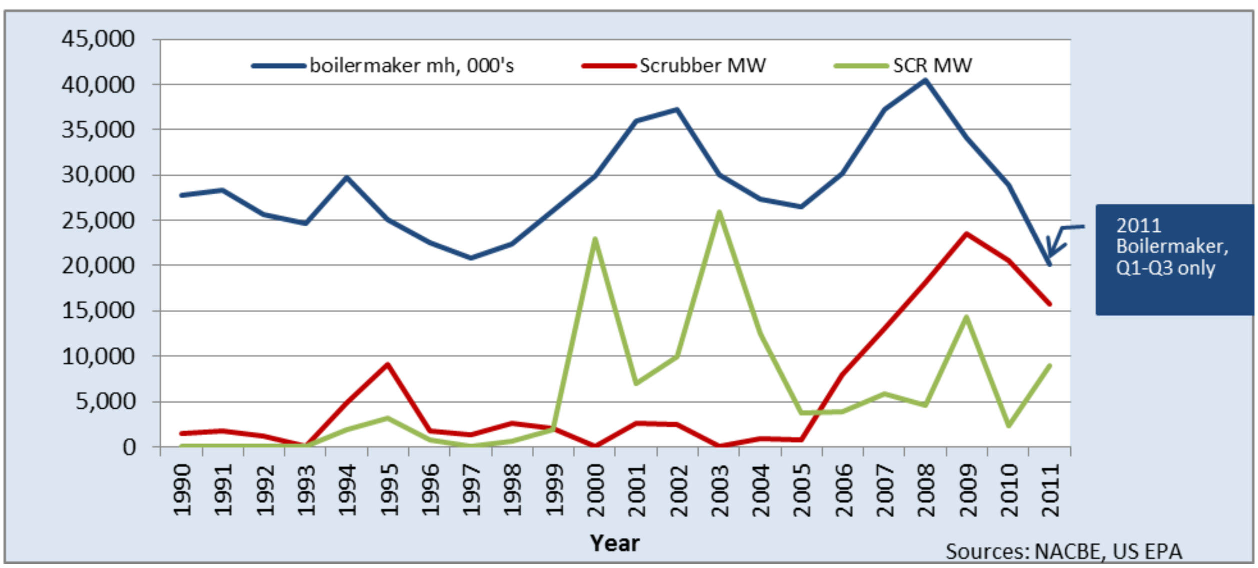
In 2004 representatives of the utility industry provided estimates of boilermaker demand that were greater than what was in the 2002 Report. These estimates were based upon five data points for FGD and twelve data points for SCR.[13] Today it is possible to look back at the experience with the NOx SIP Call and CAIR and better characterize and quantify the labor needs – especially boilermakers - for SCR and FGD systems using data representing a large population of projects.

The NOx SIP Call and CAIR resulted in a large portion of the coal fleet being retrofit with SCRs and scrubbers. Figure 2-2 is a plot of historical data of the MW capacity of SCRs and scrubbers being put on line (from NEEDS) and annual boilermaker manhours as reported by the National Association of Construction Boilermaker Employers (NACBE) for each year from 1990 through 2011.[14] NACBE's member companies are boiler construction and maintenance companies, tank contactors, and specialty construction contracting companies that serve the utility industry and other heavy industries that utilize boilermakers in construction. NACBE only tracks union boilermaker employment. Although union boilermakers comprise the large majority of boilermakers, a good estimate of the number of non-union boilermakers was not available. For this reason, the total union and non-union boilermaker numbers would be slightly higher than what is shown in Figure 2-2.

There appears in Figure 2-2 to be a correlation between start-up of air pollution control equipment and boilermaker labor, and this is reasonable to expect. As evidenced in Figure 2-2, peaks in boilermaker activity are shown in 2002, one year prior to the peak in SCRs being placed in service, and in 2008, one year prior to the peak in scrubbers being placed in service. What is also apparent is that the boilermaker labor rose quickly in response to the retrofit activities. Not shown in Figure 2-2 are low NOx combustion retrofits, which would have also influenced the demand for boilermakers, but not as much as the much larger SCR and scrubber projects.

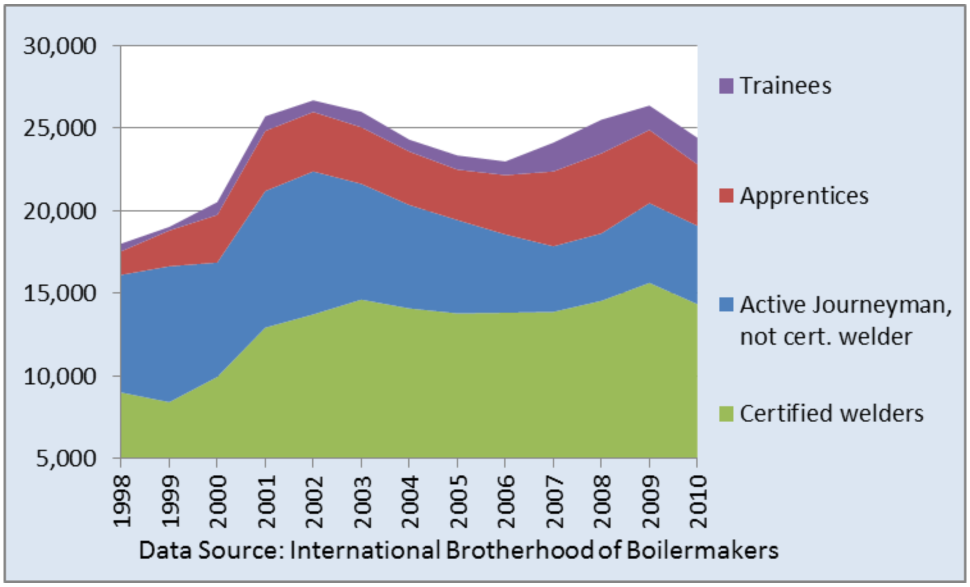
Because of the apparent correlation between boilermaker demand and retrofit of air pollution control equipment, it is possible to infer the incremental demand for boilermakers that resulted from these clean air initiatives. Two periods are of particular interest, from roughly 1999 through 2005 when mostly SCRs were installed in response to the NOx SIP Call and other initiatives, and from 2006 through 2011, when scrubbers and SCRs were installed primarily in response to CAIR.

Figure 2-2. Boilermaker manhours and new scrubber and SCR's in service on coal units



In response to the increased demand for boilermakers shown in Figure 2-2, construction boilermaker membership increased during the period of the SIP Call and during the period that the CAIR retrofits were underway. Figure 2-3 is a plot of data from the International Brotherhood of Boilermakers. As shown, the ranks of construction boilermakers increased over the two periods of 1998 to 2002 and 2006 to 2009, which are coincident with the execution of NOx SIP Call projects and CAIR projects.   In effect, the increased demand for construction boilermakers from these two clean air initiatives provided the motivation for an increase in supply of construction boilermakers.

Figure 2-3. Construction Boilermaker Membership



Although the period of 1999 through 2005 is of interest for SCR installations for the SIP Call, Figure 2-2 shows two peaks of SCR installations within this period (2000 and 2003), which makes it difficult relate the demand for boilermaker manhours to the SCRs installed over the entire period. The two peaks in SCR installations during this period are a result of multiple requirements over this period – the Ozone Transport Region NOx Budget Rule, NOx RACT for Group II Boilers, and the NOx SIP Call. Furthermore, the NOx SIP Call was delayed by a year due to a court decision, which may have led some owners to delay some ongoing SCR projects that might otherwise have been placed into service in an earlier year had it not been for the court decision. For this reason within the 1999 to 2005 period we will focus on the period 2001 through 2005. The two periods of time that are therefore examined in order to quantify the demand for boilermaker labor are:

1. Installations that went on line between 2001 and 2005, and the boilermaker manhours from 2000 through 2004.
2. Installations that went on line between 2006 and 2011, and the boilermaker manhours from 2005 through 2010.

The reason for selecting these two periods is because the nature of the technologies differed. During the first period many SCRs and very few scrubbers were installed, while the second period was a mix of scrubbers and SCRs, but more scrubbers than SCRs. Data from the first period should provide good information on boilermaker needs for SCRs.

Figures 2-4 and 2-5 are plots of boilermaker manhours versus MW of air pollution control equipment installed in the year for each of the periods 2001 through 2005 and 2006 through 2011, respectively. The boilermaker manhour data is selected from the year that precedes the air pollution control equipment installation data because the effort to install the SCR or scrubber will precede the start-up and because the peak in boilermaker activity generally preceded the peak in equipment start up by one year. As shown, there is a high degree of correlation (about 67%) between the MW of new air pollution control equipment placed in service and boilermaker demand in the prior year. This confirms expectations that there should be a high correlation between these two pieces of data[2] while also providing information helpful toward quantifying for the broader market the impact of air pollution control equipment installations on demand for labor, especially boilermakers.

The slopes of the lines in Figures 2-4 and 2-5 indicate the *average* boilermaker demand per MW of installed technology placed in service over the period. The slope of Figure 2-4 is an indicator of boilermaker demand for SCRs, since very few scrubbers were installed during this period, and this indicates that, on average, for each MW of SCR retrofit 438.5 boilermaker manhours were needed. In effect, retrofit of SCR on a 500 MW plant would require on average 219,250 boilermaker manhours. This value is an average for projects placed in service over the 2001-2005 period, as some projects would require more boilermaker labor and some less, and this is partly why the data does not plot in a perfect line with 100% correlation. Figure 2-5 has data representing a blend of SCRs and scrubbers (mostly wet scrubbers), with nearly 2.5 MW of scrubbers for every MW of SCR (99,100 MW of scrubbers versus 40,000 MW of SCR over the period). Assuming that the boilermaker demand per MW of SCR is the same on average for the SCRs placed in service during the time period of 2006-2011 as it was for those placed in service during the time period of 2001-2005, the average boilermaker demand for a scrubber placed in service over that period can be estimated as:

$$514.4 \text{ boilermaker/MW} = [40{,}000 \text{ MW} * 438.5 \text{ boilermaker m-h/MW} + 99{,}100 \text{ MW} * X]/139{,}100 \text{ MW}$$

$$X = 545 \text{ boilermaker m-h/MW}$$

Therefore, the historical boilermaker employment data suggests that:

- SCR retrofits require roughly 438.5 manhours (round up to 440 manhours) per MW
- Wet scrubber retrofits require roughly 545 manhours per MW

Figure 2-4. Boilermaker manhours (2000-2004) versus MW controls placed in service (2001-2005).

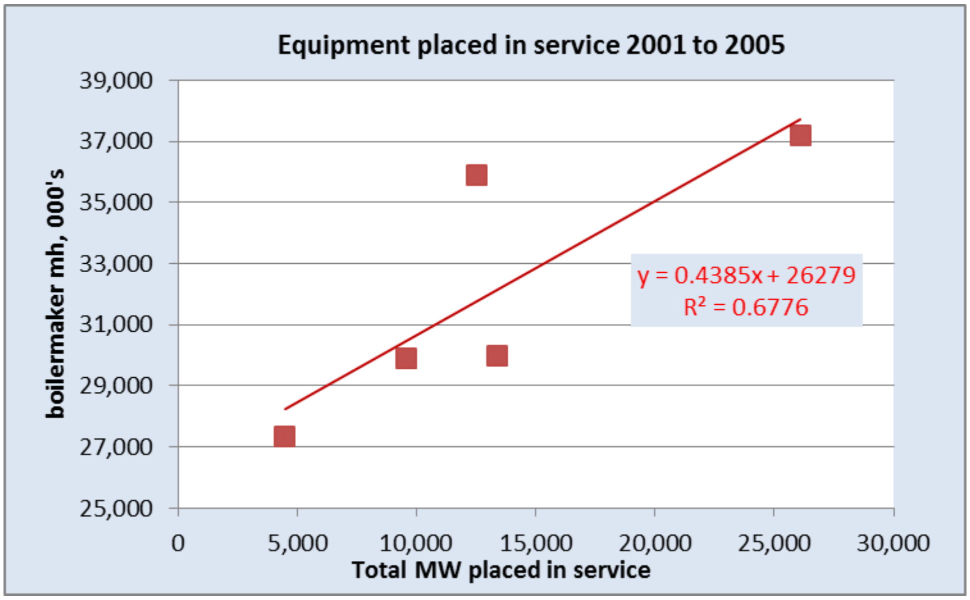
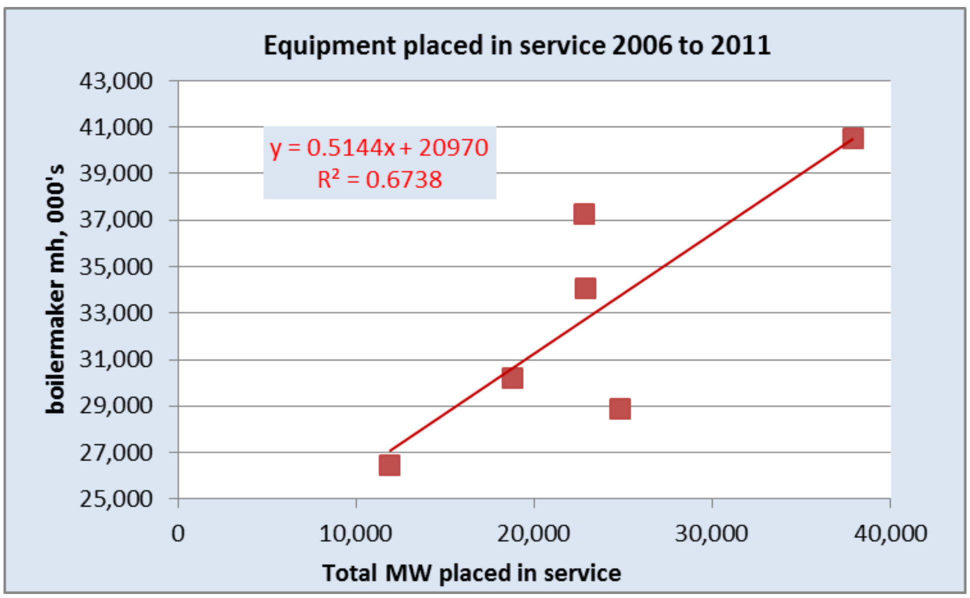


Figure 2-5. Boilermaker manhours (2005-2010) versus MW controls placed in service (2006-2011)



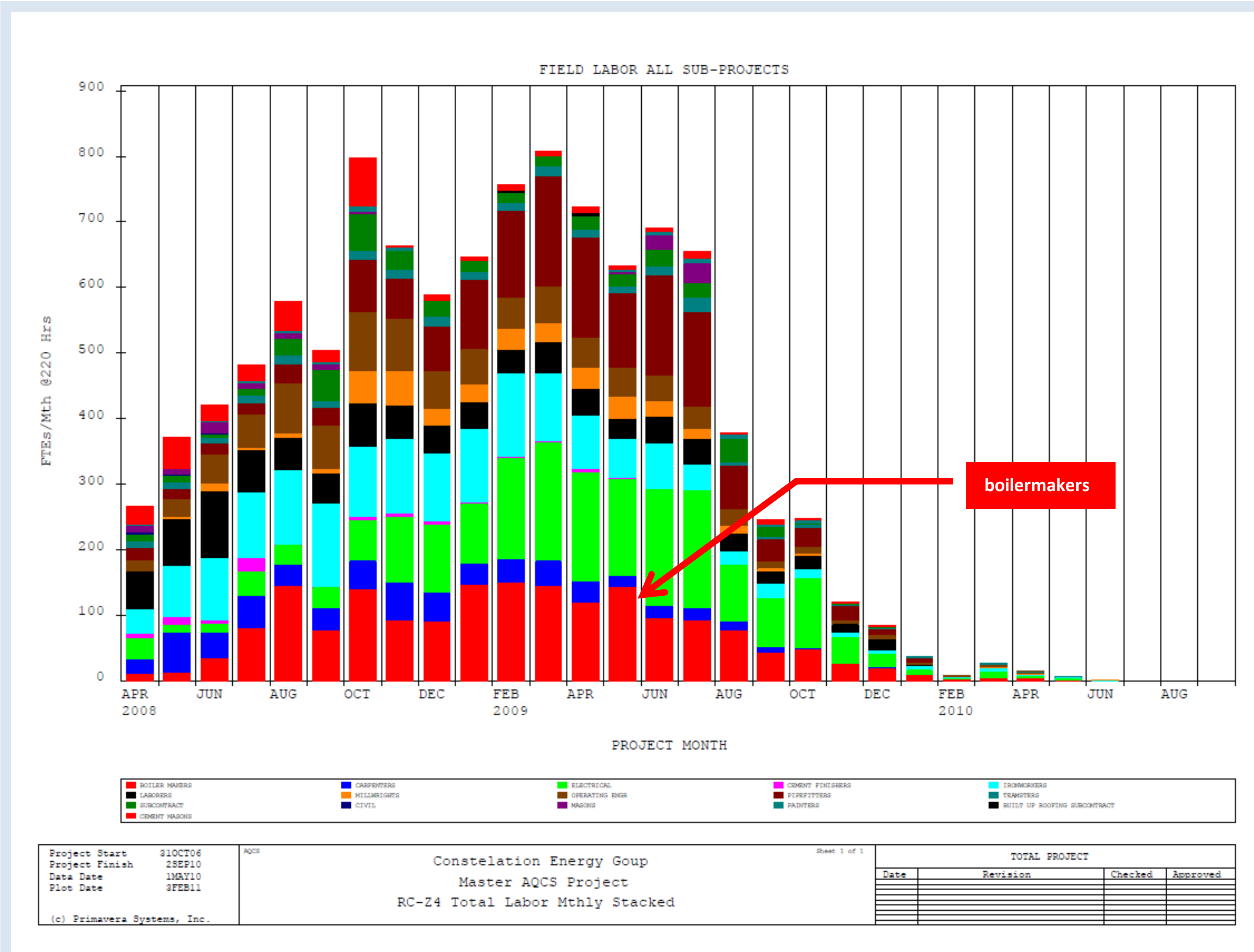
These numbers should be regarded as average, with the understanding that some projects will require more labor and some less. Any particular project might differ significantly from this. Also, these do not capture the effect of non-union boilermakers or the effect of other clean air activities (ie., low NOx combustion retrofits, etc.), which likely were small and in the net the effect on the results would likely offset one another to some degree.

Other skilled labor trades contribute to installation of SCRs and scrubbers. The 2002 Report stated that roughly 80 percent of the total FGD labor was for construction activities, with about half of that for boilermakers, and 20 percent was for engineering and management. For SCRs the 2002 Report stated that the breakdown was roughly 45% for boilermakers, 50% for other construction trades and 5% for engineering and construction management. This may have underrepresented the need for other construction trades, perhaps because the technology suppliers tend to focus on the scrubber island and associated ductwork and not on the ancillary support equipment, such as reagent preparation, chimney, water treatment, etc., which may be substantial for a particular scrubber.

The total on-site labor to build the Brandon Shores scrubbers and associated fabric filters and sorbent injection system on the 2 x 640 MW boilers was 4.3 million manhours, or 3,359 manhours per MW of installed capacity on this $885 million project, or about $691/kW.[Error! Bookmark not defined.] The Brandon Shores scrubber project included installation of fabric filters and lime injection systems, and would therefore be expected to have higher cost and manhours than for a wet scrubber alone. Figure 2-6, a plot of manhour usage by trade, shows that boilermakers (the portion on the bottom in red) were only a small portion of the total labor force (what appears to be somewhat under a fifth) necessary to install the Brandon Shores scrubbers, which is in the same range of boilermakers as what was estimated for wet scrubbers from the 2006-2011 data. So, for the remainder of the plant, there is a large demand for other construction trades, and this will depend to a large degree upon the scope of the project.

Dry FGD systems are less complex, and therefore it is expected that they would require fewer workers. Sargent & Lundy provided a cost estimate for addition of dry scrubbers on Oklahoma Gas and Electric's Sooner Units 1&2 (535 and 540 MW, respectively) and Muskogee Units 4&5 (511 ad 522 MW, respectively). For the Sooner units, the total manpower estimate was roughly 1.79 million manhours while the Muskogee unit dry FGD total manpower estimate was roughly 1.85 million manhours. [15] This equates to about 1,665 mh per MW for the Sooner units and 1,790 mh per MW for the Muskogee units. The estimate did not identify the boilermakers versus other trades. Averaging these two numbers will result in 1,727 mh (round off to 1725 mh) per MW in total labor. This is well below the labor required for the Brandon Shores FGD project, however, the scope was different and the amount of support infrastructure for a dry FGD system generally is substantially less than for a wet FGD system. It is also uncertain how representative the Sooner and Muskogee FGD dry FGD retrofits are

Figure 2-6. Field Labor Schedule for Brandon Shores Scrubbers [1]



The boilermaker requirement for a dry FGD system on a boiler of a given size would generally be the same or less than for wet FGDs or for SCRs. This is because there is less equipment in a dry FGD than a wet FGD and because SCRs tend to be particularly boilermaker intensive relative to the total effort of the project because there is so much boiler integration associated with an SCR retrofit project.

For an SCR, the retrofit activities are largely isolated to the boiler. Unlike scrubbers that can require substantial facilities for reagent preparation, dewatering, by-product removal, and water treatment, SCRs have far less support equipment needed. As a result, it is reasonable that boilermakers comprise a larger proportion of the total labor, and 40% is a reasonable estimate per the 2002 Report. This results in total labor need of 438.5 mh/MW/0.4 = 1,096 mh/MW which is roughly 1,100 mh/MW

EPA engaged Sargent & Lundy to develop updated cost models for air pollution control equipment, to include SCR and wet and dry FGD. [16, 17, 18] The example calculations for these cost models showed a cost of roughly $500/kW for a wet scrubber on a 500 MW boiler, $512/kW for a dry scrubber on a 300 MW boiler and roughly $175/kW for an SCR on a 500 MW boiler. These scrubber costs are generally consistent with the Brandon Shores wet scrubber cost (Brandon Shores is more expensive, but included a fabric filter), and the Sargent & Lundy estimate of dry FGD systems for the Sooner and Muskogee units. It is necessary to adjust for the increased labor associated with the fabric filter at Brandon Shores, and this can be done by comparison of the cost for a scrubber alone. If the total labor for the Brandon Shores air quality control system, which included a fabric filter and sorbent injection, was reduced in proportion to the cost when compared to Sargent & Lundy's cost estimate for a wet scrubber, it would result in 3,359 mh/MW x ($500/kW)/($691/kW) = 2430 mh/MW for a wet scrubber. Using this assumption and the information previously discussed in this chapter, Table 1-1 shows the approximate labor demand generated from SCR or scrubber projects.

Table 2-1. Approximate labor demand generated from SCR or scrubber projects, in mh/MW

	SCR	Wet Scrubber	Dry Scrubber
Boilermakers	440	545	*
Other Labor	660	1,885	*
Total	1,100	2,430	1,725

* *Only total manhour data was available*

Demand for and Availability of Resources Going Forward

Experience with installing scrubbers and SCRs in response to CAIR provided useful insight to the resource needs for clean air programs. Wet FGD systems are the most complex and resource-intensive air pollution control technology associated with control of criteria pollutants or air toxics, and the retrofit program undertaken for CAIR was unprecedented in size and exceeds what is envisioned in response to the MATS or the CSAPR.   Because there is a finite number of power plant boilers to retrofit with air pollution control technology, as a result of the extensive retrofit effort undertaken in response to past clean air efforts there is far less work needed for the balance of the coal fleet that still requires controls. A summary of experience from CAIR and outlook going forward for several key resources are discussed:

- *Construction Materials* – The 2002 Report determined that there was adequate supply of construction materials, such as steel; however, experience during CAIR implementation showed that global supply and demand forces could cause prices to escalate at a rapid rate. Steel requirement for scrubbers and SCRs were estimated in the 2002 Report, but it is worth reexamining here. Sargent & Lundy's estimate of the Sooner 1 & 2 dry FGD and baghouses showed roughly 5700 tons of structural and other steel, or about 5.3 tons per MW.[19] This is higher than what was estimated in the 2002 Report for wet FGD. It is likely that the earlier estimate was low because the earlier estimate was from technology suppliers and may have not included the full scope of a wet FGD project. It is reasonable to assume that a typical wet FGD project would require more steel than a dry FGD. If a dry FGD is roughly 80% of the cost of a wet FGD for a similar sized plant, and the amount of steel is assumed to be proportional to the cost, the steel for a wet FGD should be around 5.4/0.8 or 6.75 tons/MW. The 2002 Report found that steel needed for SCRs was in the range of 2.2-2.6 tons per MW. Like the estimate for steel demand for wet FGDs in the 2002 Report, this estimate was also from technology system suppliers; however, this estimate for SCR steel is probably a reasonable range since there is much less outside the scope of a technology supplier for an SCR. In any event, however, some SCR installations will require much more steel than others, and this is a function of the layout of the plant.
- *Specialty fabricators* – Because of the limited number of companies that supply large chimneys, lead times on new chimneys for wet FGDs were lengthened during the response to CAIR; however, going forward there will be far fewer wet FGD retrofits, diminishing the need for new chimneys in the future. Also, the large vessels used for FGDs, which required specialty fabrication, are not envisioned to be necessary to the extent that they were with CAIR. Availability of specialty fabricators needed for other technologies that may be used for compliance with the MATS or the CSAPR will be discussed in other chapters.
- *Engineered Equipment* – Lead times for key equipment, such as large recycle pumps were extended well beyond historical levels during the industry's response to CAIR. Since future scrubber and SCR

retrofits are not expected to be as extensive as during CAIR, these will not be an issue going forward for scrubbers or SCRs. Availability of engineered equipment needed for other technologies that may be used for compliance with the MATS or the CSAPR will be discussed in other chapters.

- *Specialty materials* – Scrubbers use special, corrosion-resistant materials and SCRs use catalyst. Because the corrosion resistant metals are traded globally, and demand was high in Asia, price on some specialty materials did rise. Availability for SCR catalyst was not an issue for SCRs built in response to CAIR because there was ample SCR catalyst manufacturing capacity built in response to the NOx SIP Call. Availability of specialty materials needed for other technologies that may be used for compliance with the MATS or the CSAPR will be discussed in other chapters.
- *Reagents* – Scrubber and SCR reagents did not prove limiting during industry's response to CAIR and are not envisioned to be limiting in the future because these reagents are already used in our economy for a wide range of other uses. Availability of reagents needed for other technologies that may be used for compliance with the MATS or the CSAPR will be discussed in other chapters.   The wet scrubber and SCR demand for reagents (limestone and ammonia, respectively) should not have changed, as these are a function of the reaction chemistry of these technologies. For dry lime scrubbers, Sargent & Lundy's example calculation showed four tons per hour of lime for a 300 MW plant with heat rate of 9800 Btu/kWh and SO2 rate of 2 lb/MMBtu.[17] This equates to 1.36 lb lime/lb of uncontrolled SO2, or roughly 1.5 lb lime/lb of SO2 reduced.
- *Labor* – Labor was envisioned to be very limiting prior to CAIR; however, it was not as limiting as anticipated. This was due to a number of factors. Going forward, far fewer scrubber or SCR retrofits are anticipated, but other technologies will draw from the same labor pool, and the impact on labor from installation of these technologies will be examined in the other chapters.

Chapter 3

Activated Carbon and Dry Sorbent Injection

Activated Carbon Injection (ACI) and Dry Sobent Injection (DSI) are both low capital cost technologies that are expected play a role in coal power plant compliance with EPA rules. With either technology, a sorbent or reagent is injected into the ductwork upstream of a particle matter (PM) control device, such as electrostatic precipitator (ESP) or Fabric Filter (FF). The injected material captures the pollutant of concern (mercury, in the case of ACI and acid gases in the case of DSI) and is subsequently captured and removed by the existing PM control device.

System Hardware

On a boiler equipped with an ESP or a fabric filter (FF) for particle collection, the configuration would look as in Figure 3-1. Both ACI and DSI are somewhat more efficient when a FF is used for particle collection because of the higher gas-sorbent contact in the filter cake. Another approach is to have injection downstream of an ESP, which would collect most of the coal fly ash, and upstream of a fabric filter (FF), which would mostly capture sorbent. This approach, which is often referred to as TOXECON, is shown in Figure 3-2. The advantages of this approach are that greater pollutant capture occurs because of the additional capture that can occur on the FF filter cake; and, because the ash is largely separated from the sorbent, fly ash marketability is not impacted by injection of the material.

A DSI or ACI System consists of the following components, as shown in the simplified schematic of Figure 3-3:

- A silo for storing the sorbent
- A metering system for metering the amount of sorbent injected into the ductwork – typically a rotary metering valve
- A pneumatic or mechanical conveying system for moving the sorbent to the injection location
- DSI systems may have in-line mills for grinding the sorbent into finer particles for injection
- An injection system for dispersing and distributing the sorbent in the boiler ductwork. The point of injection may be upstream or downstream of the air preheater and will depend upon the available locations for injection and the pollutants of concern. For units with hot-side ESPs, ACI is generally not effective when injected upstream of the hot-side ESP, but DSI may be effective for some acid gases. The injection system is principally made from piping that may split off to manifolds for injecting in multiple locations.
- Blowers to provide a carrying medium (typically two are installed for redundancy)
- Associated piping for the blowers and the distribution system.

- A control system that may utilize a programmable logic controller (PLC) or may be accommodated by the plant distributed control system (DCS)
- DSI retrofits may also require modification of the PM control system's material handling system to accommodate the higher material flow into the ESP or fabric filter.
- The principle differences between the hardware for ACI and DSI systems largely relate to the size of the storage system and the injection systems, which relate to the amount of material that is to be injected, material handling and storage, and the PM control device material handling.

Figure 3-1. Gas path for coal-fired boiler with ACI or DSI.

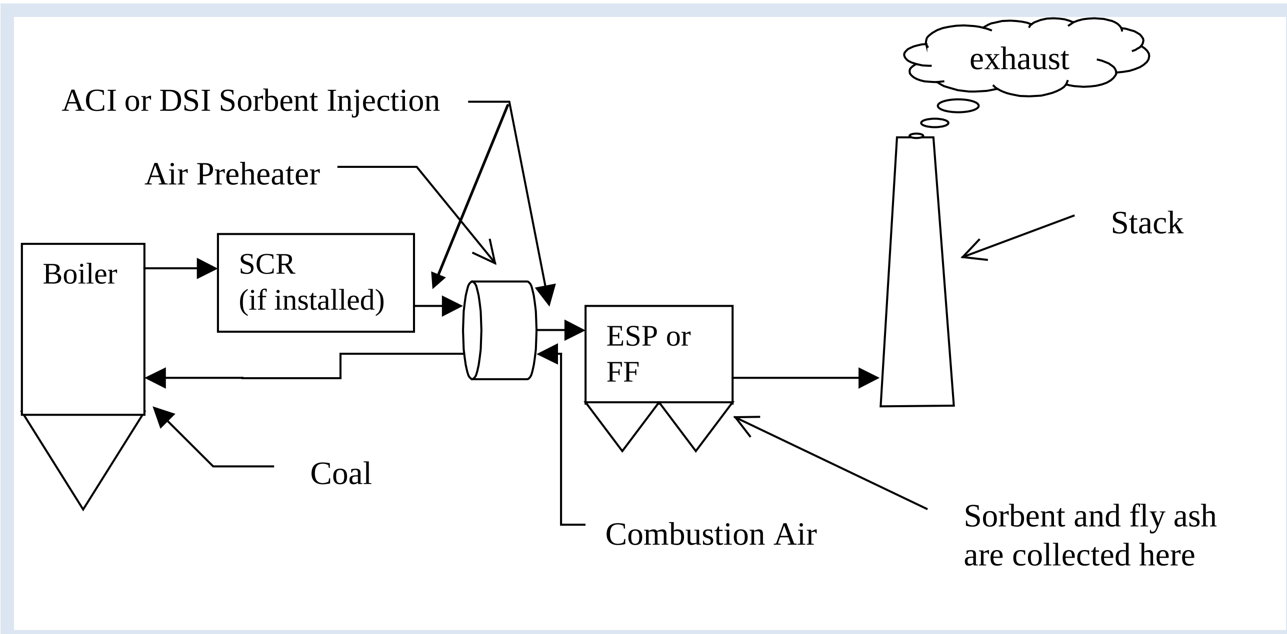


Figure 3-2. Gas path for coal-fired boiler with DSI or ACI after ESP and prior to FF.

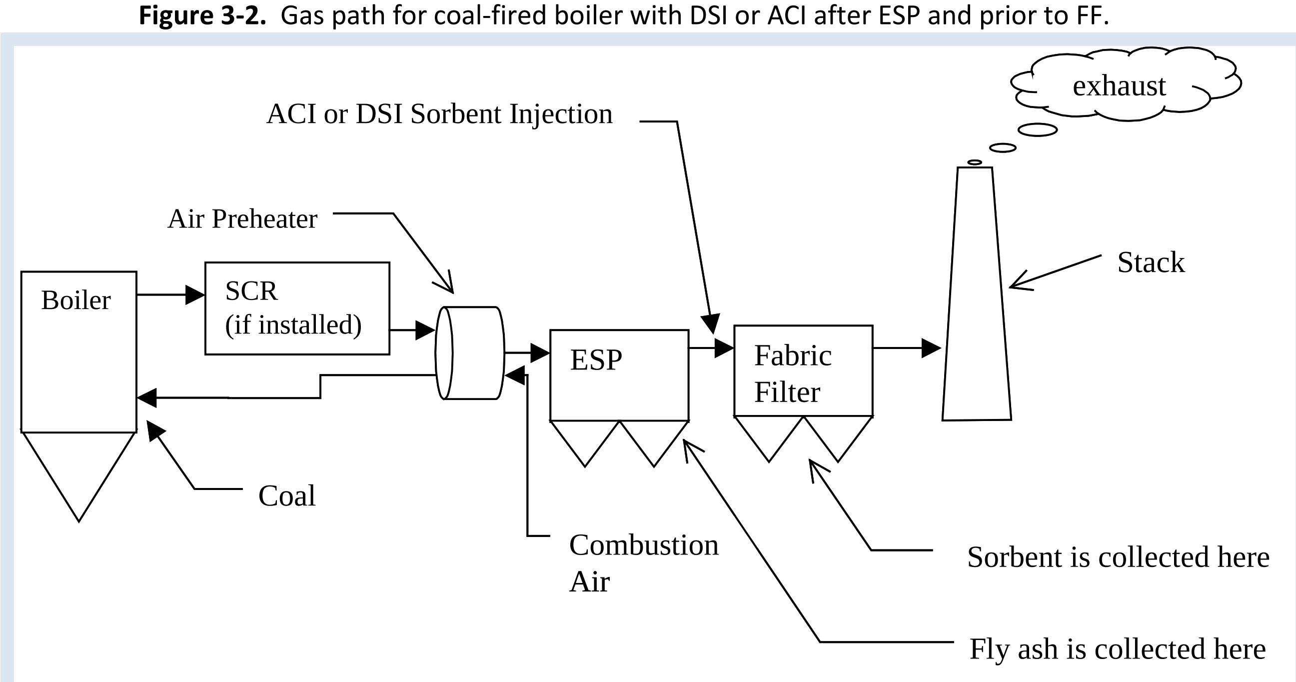


Figure 3-3. Simplified schematic of ACI or DSI system.

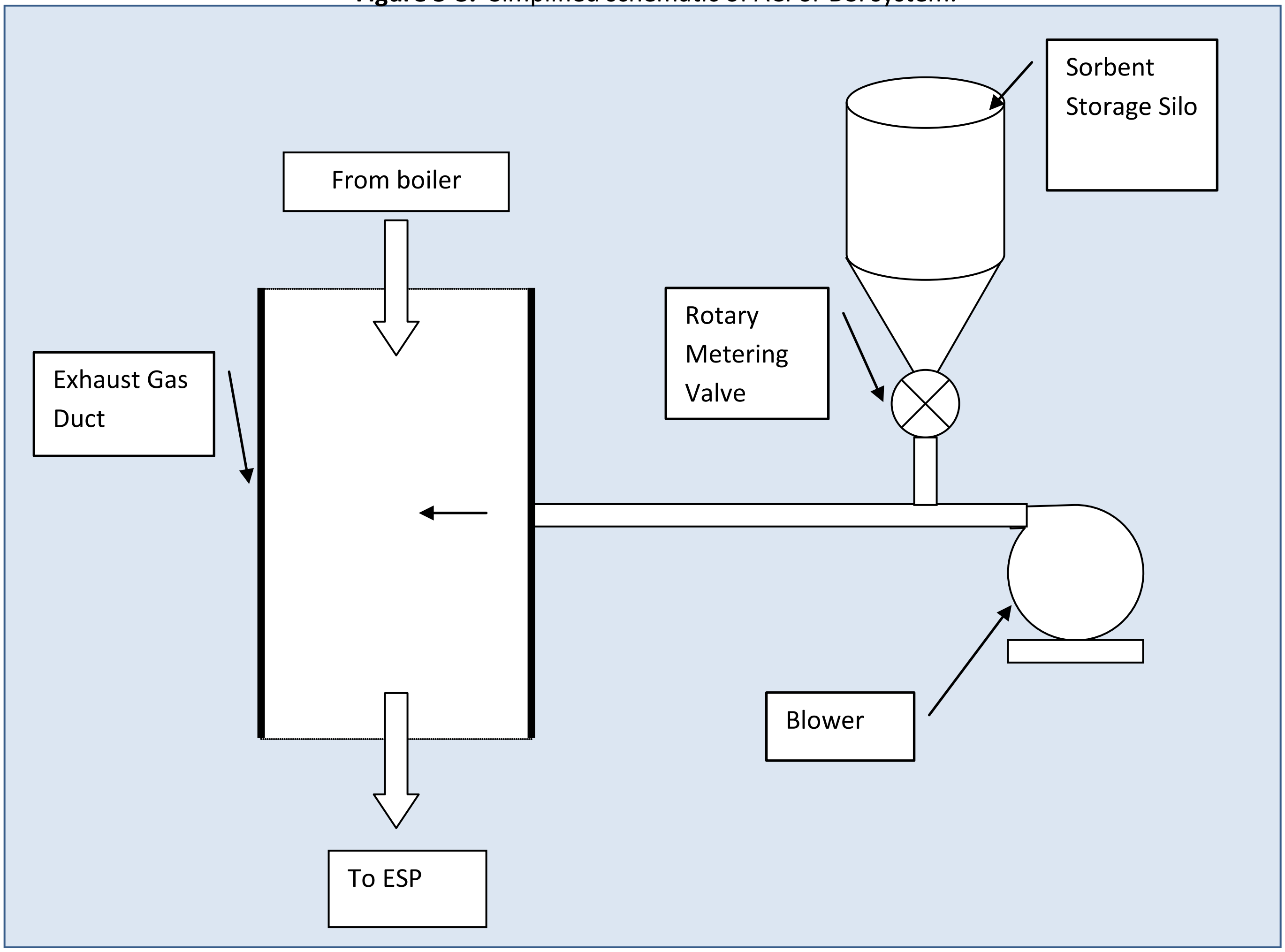
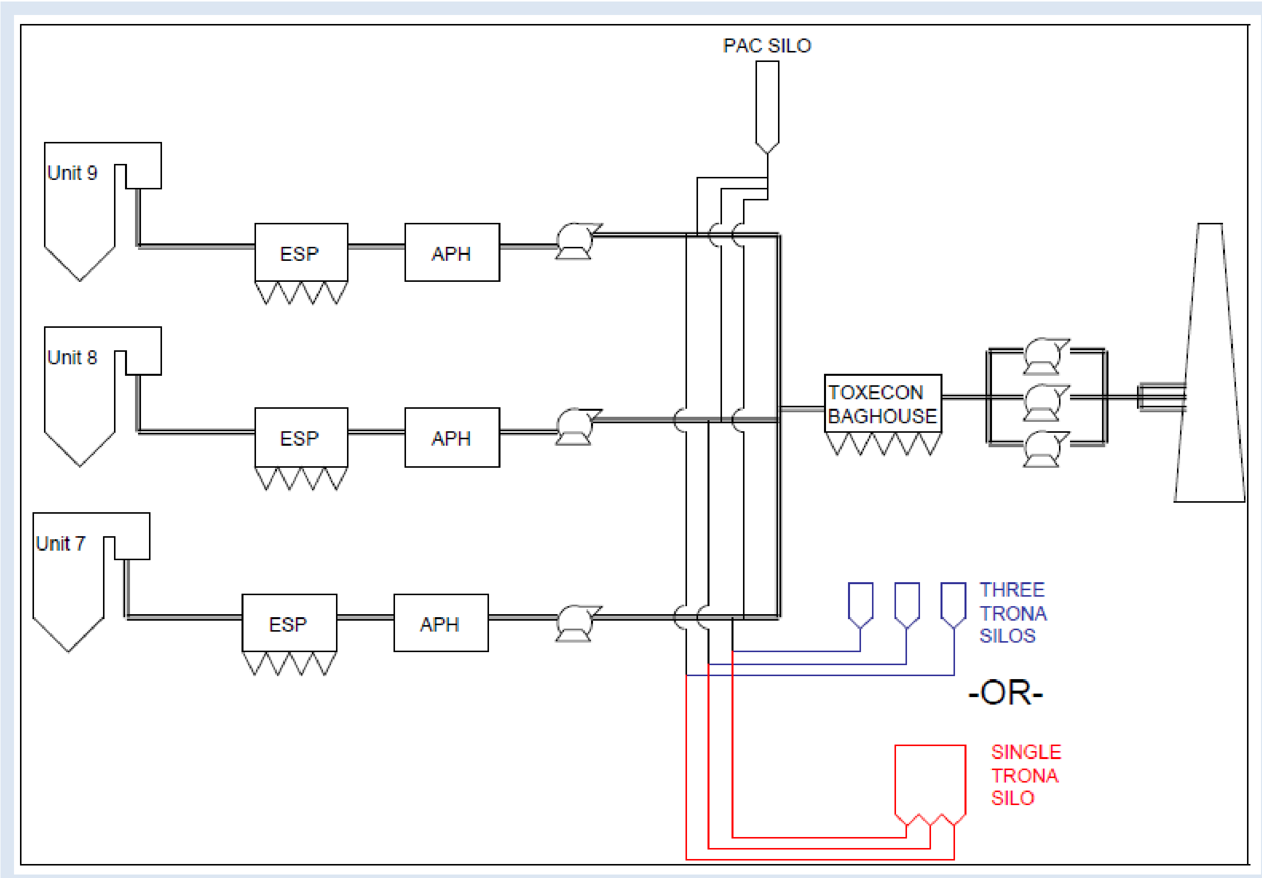


Figure 3-4 shows how a DSI system might be configured on multiple boilers, where individual storage may be used or, alternatively, a common storage silo may be used. This figure is from the Presque Isle Power Plant (PIPP) test program that was sponsored by the Department of Energy. This figure shows AC (or, denoted as PAC in the figure) being injected at the same location at the trona. There are benefits to injecting trona upstream of the air preheater, or at least upstream of the AC, in some cases. In these cases a separate set of injection lances would be necessary.

Figure 3-4. TOXECON configuration at the Presque Isle Power Plant[20]



The equipment used for an ACI system or a DSI system is assembled from standard mechanical or electrical hardware that is sold for a wide range of purposes. Table 3-1 shows a list of equipment and estimated cost for the PIPP trona injection system, which equates to \$10-\$16/kW.[20] Additional costs not shown in the table are in-line mills in the event this approach was to be used for reducing the particle size of the trona, and additional lances (note that the program relies on utilizing the same injection system as the AC). It is also likely that additional storage might be necessary. In-line mills are not necessary because trona can be delivered in a pre-milled form; however, some facility owners may choose to install in-line mills which may provide them some added flexibility in reagent supply and storage. Other than the mills, the equipment is similar to what is used for storage and pneumatic conveying of dry powder in other industries.

Table 3-2 describes the total cost of the ACI system supplied to the Gaston power plant (proposed in 2002 and delivered in 2003). This was installed upstream of a fabric filter. A system designed for upstream of an ESP would have similar equipment, but would likely cost more because of the higher AC treatment rate that would apply for an ACI system upstream of an ESP.

Table 3-1. Cost Estimate for DSI System at Presque Isle Power Plant [20]

Trona Injection System and Balance-of-Plant Equipment and Installation Costs Presque Isle Power Plant Units 7, 8, and 9		
CAPITAL COST ELEMENT DESCRIPTION	**COST**	
	1 Silo	**3 Silos**
Trona Storage/Injection System (Equipment Cost)		
• Silo (s) - Including: 75 ton Capacity Storage Silo, 1 Hopper Below Silo, 1 Blower, 1 Dehumidifier Pkg, Conveyor Piping (300 ft) • Lances (*Injection lances from test can be used in permanent system; additional lances are optional at $5,000 per lance) • Redundancy (equipment added for 3 injection lines per 1 silo), Including: Splitter Valve, 2 Hoppers, 2 Rotary Valves, 2 Blowers, 2 Dehumidifier Packages, Housing for Blowers and dehumidifiers	$ 595,000 $ 5,000* $ 98,500	$ 1,785,000 $ 5,000* $ -
Installation of Trona Storage/Injection Equipment Includes civil, electrical, mechanical and piping	$ 580,000	$ 580,000
TOTAL PROCESS EQUIPMENT	$ 1,273,500	$ 2,365,000
Increase In Ash Handling Capabilities		
• 2 Mechanical Exhauster Packages • Larger Capacity Filter/Separator (Design and Supply)	$ 15,000 $ 200,000	$ 15,000 $ 200,000
TOTAL ASH HANDLING EQUIPMENT UPGRADES	$ 215,000	$ 215,000
TOTAL EQUIPMENT COSTS (Installed Cost, TEC)	**$ 1,488,500**	**$ 2,580,000**
General Facilities (10% of TEC)	$148,850	$258,000
Engineering and Home office Fees (12.5% of TEC)	$186,062	$322,500
Project Contingency (25% of Process Equip. + 20% of Ash Handling Equip.)	$361,375	$634,250
Process Contingency (7.5% of Process Equip. + 5% of Ash Handling Equip.)	$106,262	$188,125
TOTAL PLANT COST (TPC)	**$2,291,050**	**$3,982,875**
Preproduction Costs (=(1/12)*(Fixed O&M + Var O&M)+.02*TPC)	$397,921	$431,757
TOTAL CAPITAL REQUIREMENT (TCR)	**$2,688,971**	**$4,414,632**

Table 3-2. Cost Estimate for ACI System at Gaston Power Plant [21]

Capital Costs			
Description	**Units**	**Value**	**Notes**
ACI Storage and Injection System	$	$320,000	
Piping, Manifolds, and Lances	$	$25,000	
Foundations and Steel (installed)	$	$55,000	
Electrical Supply Upgrades	$	$25,000	
Miscellaneous Utilities, Lighting		$20,000	
Controls Integration	$	$20,000	
Subtotal		$465,000	
Taxes	$	$27,900	
Freight	$	*incl*	
Purchased Equipment Cost Subtotal	$	$492,900	
Installation of Process Equipment	$	$90,000	
Total Direct Cost	$	**$582,900**	
Indirects			
General Facilities	10%	$58,290	
Engineering Fees	10%	$58,290	
Project Contingency	15%	$87,435	
Process Contingency	5%	$29,145	
Total Plant Cost (TPC)	$	**$816,060**	
Allow. for Funds During Constr. (AFDC)	$	$0	Construction period < 1yr.
Total Plant Investment (TPI)	$	$816,060	
Preproduction Costs	$	$0	
Inventory Capital	$	$0	
Total Capital Requirement (TCR)	$	**$816,060**	
	$/kW	$3.15	

Sargent & Lundy estimated the cost of ACI and DSI systems for US EPA in 2010. These studies estimated capital costs for ACI and DSI systems of roughly $7/kW and $40/kW, respectively, updated to 2010 dollars. [22, 23] The DSI system that was estimated in price by Sargent & Lundy was for SO_2 removal (and would also provide HCl removal). Sodium bicarbonate is a more efficient sorbent for SO_2 and HCl removal, providing the same SO_2 reduction at roughly half the treatment rate and for this reason would result in lower reagent and capital cost. [24] For a unit designed for SO_3 removal, a smaller DSI system than that estimated at $40/kW would be necessary due to the lower injection rates needed, and therefore would be less expensive.

Resources for ACI and DSI Systems

Construction Materials – Total steel for an ACI system on a 500 MW boiler was estimated as 175 tons, or 0.35 tons/MW, in the 2002 Report. Scaling up in proportion to cost, 0.35 x (40/7) = 2 tons/MW.

Specialty fabricators – The blowers and control valves for ACI and DSI systems are largely skid mounted. Except possibly for large storage silos, which may require a large tank or silo contractor, specialty contractors or fabricators are generally unnecessary. But, companies that construct tanks and silos are relatively common.

Engineered Equipment – DSI and ACI systems use components such as blowers, metering valves and associated control equipment that are fairly commonly used for conveying dry powders in a number of industrial applications. For this reason the availability of equipment is not expected to become a bottleneck for installing these systems.

Specialty materials – DSI and ACI systems do not require special materials, as most equipment is manufactured from steel. Unlike wet scrubbers, which present special material problems due to corrosion, corrosion is not a significant concern for DSI or ACI systems.

Reagents – DSI and ACI systems require special reagents or sorbents. In the case of ACI, it is powdered activated carbon (AC). In the case of DSI, the reagent is alkali or alkaline material, typically Trona, sodium bicarbonate, or activated lime hydrate.

For AC, the treatment rates can be estimated conservatively to be roughly as shown in Table 3-2 for boilers with ESPs firing Bituminous or Subbituminous coals or with units with a baghouse firing any coal. With an ESP, the treatment rate for lignite fired units will be similar to those of a subbituminous unit, but the bituminous unit treatment rate could be selected to be more conservative. Treatment rates are based upon those developed by Sargent & Lundy [22].

Table 3-2. AC treatment rates

	ESP	FF
lb/MMACF	5	2
lb/MWh	**1.24**	**0.50**
lb/hr for 500 MW	**621**	**248**

Activated carbon (AC) is produced by heating of a carbonaceous material, typically coal but sometimes other materials, and partially burning off material in a controlled fashion to create a highly porous material with high internal surface area. AC is manufactured in special furnaces that are designed for this purpose. For mercury control, the AC is milled to a fine powder, called powdered activated carbon (PAC). The demand for PAC as a result of the MATS and state requirements is estimated by some to be in the range of 500 million to 750 million pounds.[25] This is consistent with EPA's analysis in the MATS rule proposal.[26] In 2005, world capacity for activated carbon was estimated at 1.6 billion pounds with half of that capacity in the United States and China.[27] However, since that time, there has been a substantial amount of PAC capacity installed in North America specifically in anticipation of demand to be generated by mercury control demand.

- Norit Americas, added a 30 million pound per year PAC plant at the Bienfait mine in Saskatchewan, Canada and has plans to add three more plants at the site. [28]
- Calgon Carbon added 70 million pounds per year of PAC production capacity for the mercury market in 2009, will have additional capacity for up to 70 million pounds per year by 2012 and has completed plans for additional new capacity. [29]
- ADA Carbon Solutions has built a new activated carbon plant with about 150 million pound per year PAC capacity with the ability to double the capacity within the permit. ADA has additional activated carbon production sites identified and could bring more lines into production. [30, 31]

As a result of the existing capacity, the capacity expansions, new PAC plants, and the ability of the major producers to bring additional capacity on line, it is anticipated that there will be adequate PAC production to meet the requirements of the rule.

Trona and sodium bicarbonate are the most widely tested DSI reagents because of the high reactivity of these reagents and because, when injected upstream of an ESP, they will actually improve ESP performance due to the beneficial effects on fly ash resistivity. For a 500 MW boiler firing 2 lb SO2/MMBtu coal and a heat rate of 9800 Btu/kWh, Sargent & Lundy estimated that 16.33 ton per hour would be injected, *or 3.3 lb of trona per lb of SO_2 treated in the flue gas.*[23] If sodium bicarbonate is used in lieu of Trona, this will reduce the demand for mined trona substantially. Although sodium bicarbonate can be made from trona, it is far more reactive. Based upon data from Solvay, far less sodium bicarbonate is needed – perhaps on the order of 40% less – than trona.[32] Injected upstream of a fabric filter, similar injection rates might be used but higher removal efficiencies would result. *On the other hand, if injecting for the purpose of SO_3 control, significantly lower injection rates would result*.

Trona is a naturally occurring mineral that is used to make soda ash (sodium carbonate) as well as sodium bicarbonate (ie., baking soda) and it is also used for DSI systems. The US is the second largest producer after China, with most production in Wyoming and some in California. According to the US Geological Survey, total Wyoming trona production in 2010 was 15.9 million metric tons and the United States has the world's largest natural deposit of trona. [33] This deposit is in Green River, WY, and is estimated to have approximately 47 billion tons.[34] Trona is mainly used to make soda ash or other sodium compounds. The primary uses of soda ash are for glassmaking, soaps and detergents, and inorganic chemicals. USGS estimates that in 2010 the US soda ash producers were producing at only about 73% of capacity. As a result, the industry was running well short of capacity in 2010.[33] Trona can be and is processed to produce sodium bicarbonate. Sodium bicarbonate is also produced from natural nahcolite deposits, nahcolite being a naturally-occurring form of sodium bicarbonate.

Lime is another possible reagent for DSI which may be more useful upstream of baghouses or when there is a large ESP installed. The dry product of lime DSI is not as water soluble as that of trona DSI, which is advantageous relative to sodium-based sorbents; however, lime does not improve ESP performance in the manner that sodium DSI reagents do. Therefore, lime is likely to be an attractive sorbent upstream of baghouses or large ESPs. Lime used for the purpose of DSI would likely be an activated lime hydrate. Lime is used in a wide range of industries: Chemicals, Metallurgical, Construction, Environmental, and other purposes. Total lime production and consumption in the United States has declined in recent years. Production has declined from 21 million metric tons in 2006 to 18.3 million metric tons in 2010 along with consumption.[35]

Labor – The man-hours of labor estimated to be required for supply of an ACI system are listed in Table 3-3, which includes a breakdown of man-hours by task. Craft labor for installation is also indicated.

Assuming that manhours are proportional to cost, a DSI system for a 500 MW plant would require roughly (40/7) x 4800 mh (9.6 mh/MW), or about 27,500 mh (55 mh/MW).

Table 3-3. Estimated Man-hours for Supply of an ACI System for a 500 MW_e 0.6% S Bituminous Coal Boiler with ESP
(from 2002 Report)

Task	Man-hours
Off-Site Engineering and On-Site Testing	1,600
Installation, except silo (ironworkers, pipe fitters, electricians)	1,200
Erection of Silo (ironworkers, pipe fitters)	2,000
Total Man-hours*	4,800

**Estimated time for engineering, design, equipment procurement, and assembly is 6 months.*

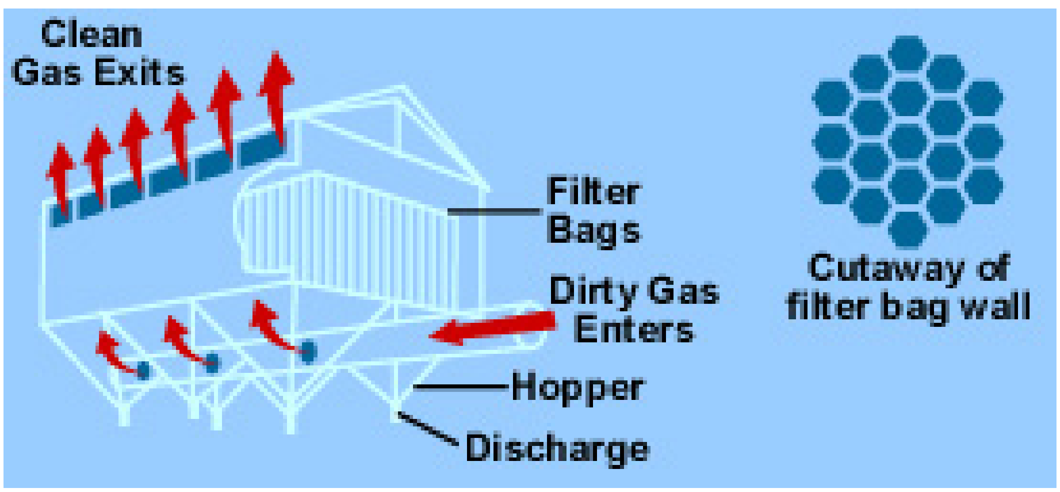
Installation Time - The 2002 Report determined that the period from start of design through engineering, procurement, installation and commissioning of an ACI system would be under 18 months, and likely installation times are under one year. Sargent and Lundy estimated less than a one year engineering and construction cycle for both DSI and ACI. [22, 23] One would expect a similar time frame for DSI systems because of the similarity of the equipment, and this is consistent with the findings in a study by URS.[36]

Chapter 4

Fabric Filter Systems

Fabric filter (FF) systems, more commonly called “baghouses”, operate by passing dust-laden gas through a filter that is made from a fabric. Most baghouses are either reverse-air baghouses or pulse-jet baghouses, the name referring to the type of bag cleaning method. Pulse-jet fabric filters (PJFF) have replaced earlier reverse-air designs as the dominant fabric filter technology and is the type of baghouse that would be installed in response to the MATS. In a PJFF the gas enters the bottom of a large “box”, turns up and must pass through any of several fabric filter “bags”, from the outside of the bag to the inner part of the bag. A metal cage prevents the bag from collapsing as the gas passes from the outside to the inside. Clean gas then passes upwards, through the bag opening, into a plenum and then exits the baghouse. Dust builds up on the fabric over time, and this is referred to as the “filter cake”. The dust must periodically be cleaned off of the bags by pulsing gas in the reverse direction and allowing the dust to fall into the hoppers at the bottom of the baghouse. Figure 4-1 shows a cutaway schematic of a PJFF, which is the type of baghouse that is most often sold to coal power plants today.

Figure 4-1. A cutaway schematic of a pulse-jet fabric filter (PJFF)
http://www.epa.gov/apti/course422/images/baghouse.jpg



Retrofit of fabric filter systems may be necessary on some coal-fired boilers in order to comply with the requirements of the MATS. Fabric filters capture filterable PM and also provide cobenefit reduction of mercury emissions and condensable PM emissions. DSI systems and ACI systems will be more effective when followed by a fabric filter than when followed by an ESP.

Except when followed by a wet scrubber, a fabric filter is normally the final air pollution control device before the chimney.

Equipment Needed for a FF Retrofit

A fabric filter retrofit will normally entail the following:

- A fabric filter with filter bags (filter bags must periodically be replaced)
- A booster fan and fan controls
- Compressed Air System
- Ductwork, to include dampers, etc.
- Fly ash handling system
- Instrumentation and Control system, normally PLC-based

Table 4-1 shows equipment and reported costs for a TOXECON system installed at the Presque Isle Power Plant (PIPP) that includes a PJFF and an ACI system. [37]

Labor Requirements

The installed cost for the TOXECON system for the three 90 MW boilers was $128/kWe. At current material and labor costs, the cost would be somewhat higher. The proportion of cost attributed to various project labor costs are as follows:

Mechanical Erection:	22.5% of total cost
Construction Supervision and Indirects:	4.8% of total cost
Foundations :	4.6% of total cost
Electrical Installation:	4.2 % of total cost
Engineering:	11.4% of total cost
Total Project Labor as percentage of cost:	*47.5% of total cost*

The above costs may have included some materials, but these are likely to be small compared to the labor component of the costs. These costs also do not include the labor associated with fabrication of equipment or manufacture of materials used for the TOXECON system.

ATP contacted five suppliers of air pollution control equipment to estimate the labor needed for a fabric filter project and asked the respondents to compare the labor to that for an SCR. The average for all respondents that replied was that:

- Fabric Filters require roughly 85% of the boilermaker labor as an SCR

Since it was estimated that SCRs required roughly 438.5 mh/MW of boilermaker labor, a fabric filter is estimated to required roughly 0.85 * 438.5 mh/MW = 373 mh/MW of boilermaker labor. Of course, this is simply an approximate number and for any given project the actual labor needs could vary significantly depending upon the particular details of the project.

Sargent & Lundy's estimate of the Sooner Units 1 & 2 dry FGD and baghouses showed roughly 840,000 manhours of labor or about 780 mh/MW of labor, excluding the activities that were directly associated with the dry scrubber (dry scrubber, recycle system, makeup water, etc.).[19] Boilermaker labor was not spelled out in the Sargent & Lundy estimate. Therefore, using the earlier estimate of 375 mh/MW for boilermakers and 780 mh/MW total, the non-boilermaker labor should be roughly 405 mh/MW.

Table 4-1. Equipment and Costs for a TOXECON System with PJFF [37]

TOXECON™ and Balance-of-Plant Equipment and Installation Costs Presque Isle Power Plant Units 7, 8, and 9	
Item Description	**Cost**
Baghouse	
Baghouse Supply and Erection	$9,728,779
Equipment	
Electrical Equipment	$624,102
Controls (Including Enclosure)	$295,295
Air Compressor/Dryer	$121,589
ID Booster Fans	$1,199,802
Ash System	$623,789
PAC System	$360,786
Dampers	$655,744
Expansion Joints	$101,519
Ductwork and Structural Steel	$3,114,209
Erection	
Construction Supervision and Indirects	$1,659,883
Foundations	$1,603,112
Electrical Installation	$1,455,979
Mechanical and Structural Installation	$7,796,968
Other	
Engineering Costs (A/E and Utility)	$3,949,052
Mercury Continuous Emissions Monitors (2)	$1,353,629
TOTAL ***(excludes testing program costs)***	**$34,644,237**

Installation Time

The PIPP TOXECON project design and construction lasted from March 2004 to January 2006 with some key milestone as listed below. [37, 38]

- March 2004 – Cooperative Agreement signed between WE Energies and DOE and commencement of design
- June 2004 – Design Review Meeting
- Second quarter 2004 – Baghouse bid packages issued
- June 2004 – Baghouse vendor selected
- July 2004 – start of demolition/relocation of existing equipment
- Third and Fourth Quarter 2004 – equipment design/selected and ordered (fans, compressed air, ash handling, ductwork, etc.)
- Fourth quarter 2004-First Quarter 2005 – Foundations for baghouse, motor pedestals, PAC silos, and ductwork
- First quarter 2005 – Construction packages issued for baghouse erection
- First quarter-Fourth quarter 2005 – erection of all structural steel, baghouse, ductwork, dampers, fans, etc.
- December 2005 – Baghouse on line with flue gas of unit 7 boiler
- January 27, 2006 – tie in to units 8 and 9 completed

The entire period from commencement of design to completion of tie-ins was under 2 years. Commissioning would have added a couple of months, making it roughly two years.

ATP surveyed suppliers of air pollution control equipment to determine the time needed to perform fabric filter retrofits. The average for all respondents was that:

- Estimated time for engineering/procurement prior to placing an order was 3 months
- Estimated time from placing the order to completion of commissioning was 23 months

This is roughly consistent with the time frame experienced for the PIPP TOXECON retrofit.

Resource Requirements

- *Construction Materials* – Using the Sargent & Lundy estimate of the Sooner Units 1 & 2, and excluding the steel associated with the absorber and associated equipment (reagent prep, reagent handling, recycle system, etc.), the total steel was roughly 4100 tons (roughly 3.8 tons per MW), with roughly half or more of this associated with the ductwork. This is roughly the steel needed for the fabric filter, if that were to be installed without the upstream scrubber. It should be noted that the actual steel requirement for any particular project will be greatly affected by the ductwork runs, which are determined by the plant layout. So, there will be significant variation from site to site.
- *Specialty fabricators* – Fabric filters will often require large sections of ductwork and steel sections, but these are manufactured from mild steel since corrosion is not a major concern, as it was for construction of wet scrubbers. If transport to the site by barge is possible, it is often desirable to have large sections fabricated off-site to minimize the on-site fabrication, and this will be a case-by-case determination. Because baghouse fabricated sections are generally flat (“box-like”) and use

mild steel, unlike the shapes and materials needed for scrubber absorber vessels, fabrication of baghouse sections does not require as much specialized equipment or skills as fabrication of scrubber sections.

- *Engineered Equipment* - Engineered equipment includes primarily large fans, motors, and compressed air systems. Compressed air systems are used for a wide range of industrial applications and should not result in a bottleneck. Large fans and motors could see an increase in lead times, but not likely to the extent that was observed with large scrubber recycle pumps since large fans and motors are used in many industrial applications. Even in the unlikely chance that lead times reached what they were with large recycle pumps for wet scrubbers – two years – it would be possible to install the equipment.
- *Specialty materials* – Filter bags are an essential component of every fabric filter. Although other materials are used, the most commonly used filter bags are made from polyphenylene sulfide (PPS) and have a felt backing and/or perhaps a polytetrafluoroethylene (PTFE) membrane. Felt or membrane filter bags are specified based upon the fly ash characteristics and the desired performance. PPS is manufactured in the US, Japan and China by different suppliers. The fabric must then be felted or coated and made into a bag, and this is done by a number of suppliers, such as General Electric BHA, Gore, Midwesco Filtration and others. Because there are multiple bag suppliers, each with the ability to increase capacity if needed, it is not envisioned that there will be shortages in supply of filter bags.
- Reagents – No reagents are used for fabric filter systems.
- Labor – Installation of fabric filters will use many of the same construction laborers as used to install scrubbers, however, in smaller quantities than for scrubbers. It was determined that roughly 375 mh/MW of boilermaker labor may be required for a fabric filter retrofit and 405 mh/MW of other labor may be needed, for a total labor requirement of roughly 780 mh/MW of fabric filter installed. The experience with installing scrubbers and SCRs during the industry's response to CAIR demonstrated that there is adequate labor capacity to support installation of fabric filters.

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