United States Government Accountability Office

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Report to the Chairman, Subcommittee on Oversight, Committee on Environment and Public Works, U.S. Senate

May 2011

AIR QUALITY

Information on Tall Smokestacks and Their Contribution to Interstate Transport of Air Pollution

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GAO-11-473

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Highlights

Highlights of GAO-11-473, a report to the Chairman, Subcommittee on Oversight, Committee on Environment and Public Works, U.S. Senate

Why GAO Did This Study

Tall smokestacks—stacks of 500 feet or higher, which are primarily used at coal power plants—release air pollutants such as sulfur dioxide (SO_2) and nitrogen oxides (NO_x) high into the atmosphere to help limit the impact of these emissions on local air quality. Tall stacks can also increase the distance these pollutants travel in the atmosphere and harm air quality and the environment in downwind communities. The 1977 amendments to the Clean Air Act encourage the use of pollution control equipment over dispersion techniques, such as tall stacks, to meet national air standards. Section 123 of the Act does not limit stack height, but prohibits sources of emissions from using the dispersion effects of stack heights in excess of a stack's good engineering practice (GEP) height to meet emissions limitations.

GAO was asked to report on (1) the number and location of tall stacks of 500 feet or higher at coal power plants and when they began operating; (2) what is known about such stacks' contribution to the interstate transport of air pollution and the pollution controls installed at plants with these stacks; and (3) the number of stacks that were built above GEP height since 1988 and the reasons for this. GAO analyzed Energy Information Administration (EIA) data on power plants, surveyed states with tall stacks, and interviewed experts on the transport of air pollution. GAO is not making recommendations in this report. The Environmental Protection Agency and the Department of Energy stated they had no comments on this report.

View GAO-11-473 or key components.
For more information, contact David Trimble at (202) 512-3841 or trimbled@gao.gov.

What GAO Found

According to analysis of EIA data, which were updated with GAO's survey results, a total of 284 tall smokestacks were operating at 172 coal power plants in 34 states, as of December 31, 2010. Of these stacks, 207 are 500 to 699 feet tall, 63 are 700 to 999 feet tall, and the remaining 14 are 1,000 feet tall or higher. About one-third of these stacks are concentrated in 5 states along the Ohio River Valley. While about half of tall stacks began operating more than 30 years ago, there has been an increase in the number of tall stacks that began operating in the last 4 years, which air and utility officials attributed to the need for new stacks when plants installed pollution control equipment.

Stack height is one of several factors that contribute to the interstate transport of air pollution. According to reports and stakeholders with expertise on this topic, tall stacks generally disperse pollutants over greater distances than shorter stacks and provide pollutants greater time to react in the atmosphere to form ozone and particulate matter. However, stakeholders had difficulty isolating the exact contribution of stack height to the transport of air pollution because this is a complex process that involves several other variables, including total emissions from a stack, the temperature and velocity of the emissions, and weather. The use of pollution controls, which are generally installed in boilers or the duct work that connects a boiler to a stack, has increased in recent years at coal power plants. However, GAO found that many boilers remain uncontrolled for certain pollutants, including several connected to tall stacks. For example, GAO found that 56 percent of boilers attached to tall stacks lacked scrubbers to control SO_2 and 63 percent lacked post-combustion controls to capture NO_x emissions. In general, GAO found that boilers without these controls tended to be older, with in-service dates prior to 1980.

GAO identified 48 tall stacks built since 1988—when GEP regulations were largely affirmed in court—that states reported are subject to the GEP provisions of the Clean Air Act and for which states could provide GEP height information. Of these 48 stacks, 17 exceed their GEP height, 19 are at their GEP height, and 12 are below their GEP height. Section 123 of the Clean Air Act defines GEP as the height needed to prevent excessive downwash, a phenomenon that occurs when nearby structures disrupt airflow and produce high local concentrations of pollutants. Officials reported that a variety of factors can influence stack height decisions. For example, some utility officials reported that stacks were built above GEP to provide greater protection against downwash or to help a plant's emissions clear local geographic features, such as valley walls. GAO was unable to obtain GEP height information for an additional 25 stacks that were built since 1988 for two reasons: (1) some of these stacks were exempt from GEP regulations, and (2) states did not have GEP information readily available for some replacement stacks because the GEP calculation was sometimes made decades earlier and a recalculation was not required at the time the replacement stack was built.

Contents

Abbreviations

CAIR	Clean Air Interstate Rule
CAMx	Comprehensive Air Quality Model with Extensions
DOE	Department of Energy
EIA	Energy Information Administration
EPA	Environmental Protection Agency
ESP	electrostatic precipitator
FGD	flue gas desulfurization
GEP	good engineering practice
NAAQS	National Ambient Air Quality Standards
NESCAUM	Northeast States for Coordinated Air Use Management
NO_x	nitrogen oxides
SCR	selective catalytic reduction
SNCR	selective non-catalytic reduction
SIP	State Implementation Plan
SO_2	sulfur dioxide

United States Government Accountability Office
Washington, DC 20548

May 11, 2011

The Honorable Sheldon Whitehouse
Chairman
Subcommittee on Oversight
Committee on Environment and Public Works
United States Senate

Dear Mr. Chairman:

Tall smokestacks—which are used primarily at coal power plants—release air pollutants such as sulfur dioxide (SO_2), and nitrogen oxides (NO_x) high into the atmosphere to help disperse them and limit their impact on air quality in local communities.[1] However, because wind currents are generally faster at higher elevations, tall stacks can increase the distance that these pollutants travel, harming air quality in downwind communities. When these pollutants are airborne, they can react in the atmosphere to form particulate matter, acid rain, and ozone that can harm air quality, human health, and the environment. For example, SO_2, NO_x, ozone, and particulate matter can cause or worsen respiratory diseases such as emphysema, bronchitis, or asthma, while acid rain can damage vegetation and aquatic ecosystems.

Under the Clean Air Act, the Environmental Protection Agency (EPA) is responsible for setting National Ambient Air Quality Standards (NAAQS) for certain pollutants considered harmful to public health and the environment. EPA has set NAAQS for six such pollutants, known as criteria air pollutants: SO_2, NO_x, particulate matter, ozone, carbon monoxide, and lead. These standards are expressed as concentration limits averaged over time, and compliance is determined through ground-level monitoring at a local level. States are responsible for developing and implementing plans, known as State Implementation Plans (SIP), to achieve and maintain these standards. In carrying out this duty, states set emissions limitations for individual sources of air pollution, which are based, in part, on the results of air quality models that show the impact these sources will have on air quality. Since 1990, the Clean Air Act has required the incorporation of these emissions limitations into operating

[1]For the purposes of this report, we consider tall smokestacks to be those that are 500 feet or higher.

permits which collect all of the pollution control, recordkeeping, and reporting requirements applicable to individual sources of air pollution.

In the early 1970s, power plants commonly installed tall stacks to reduce pollutant concentrations at ground level to help attain NAAQS. The 1977 amendments to the Clean Air Act encouraged the use of pollution control equipment and other control measures over dispersion techniques such as tall stacks to meet NAAQS. For example, section 123 was added to prohibit states from counting the dispersion effects of stack heights in excess of a stack's good engineering practice (GEP) height when determining a source's emissions limitation. Section 123 of the Clean Air Act defines GEP height as the height needed to disperse pollutants to prevent excessive "downwash," a phenomenon that occurs when nearby structures disrupt airflow and produce excessively high concentrations of pollutants in the immediate vicinity of the source. Section 123 generally applies to stacks built since December 31, 1970, but some stacks may be exempt if they were built to replace stacks that were in existence on or before this date. Since the GEP heights for smokestacks can be determined using a calculation that accounts for the height and width of the largest nearby structure, GEP heights vary accordingly.[2] Section 123 does not limit stack height; instead, it removes an incentive to build stacks higher than necessary. For example, if a stack's GEP height is 600 feet, but the stack is built to 800 feet, the source cannot count the dispersion effects associated with the excess 200 feet toward meeting its emissions limitation. EPA finalized regulations for calculating and using GEP height in 1985, and these regulations were largely affirmed by the District of Columbia Court of Appeals in 1988.

EPA reported that measured levels of SO_2 and NO_x, along with ozone and particulate matter, decreased between 1990 and 2008. However, EPA noted that in 2008, about 127 million people lived in counties where one or more NAAQS—usually ozone or particulate matter—was exceeded. In developing policy to control air pollution, EPA recognizes that emissions from upwind states can contribute to the nonattainment—or

[2]Federal regulations further define GEP as the higher of 65 meters (about 213 feet), the results of a calculation based on the dimensions of nearby structure(s), or the results of a fluid modeling demonstration. The calculation based on the dimensions of nearby structure(s) that applies to stacks built after January 12, 1979, states that GEP = H + 1.5 L, where H is equal to the height of nearby structure(s) and L is equal to the height or width of nearby structure(s), whichever is less. For stacks built since December 31, 1970, and in existence on January 12, 1979, this calculation is GEP = 2.5H, where H is equal to the height of nearby structure(s).

exceedances—of NAAQS in downwind states. EPA has taken steps to reduce SO_2 and NO_x emissions that contribute to the interstate transport of air pollution through recent rule makings.

You asked us to provide information on the use of tall smokestacks at coal power plants. Specifically, our objectives were to examine (1) the number and location of smokestacks 500 feet or higher that are operating at coal power plants across the United States, and when they began operating; (2) what is known about these smokestacks' contribution to the interstate transport of air pollution and the pollution controls that have been installed at coal power plants with these stacks; and (3) the number of these smokestacks that were built above their GEP height since 1988, and the reasons for this.

To identify the number and location of smokestacks at coal power plants that were 500 feet or higher on December 31, 2010, we analyzed data on power plants from the Department of Energy's (DOE) Energy Information Administration (EIA). We also used these data to determine when these stacks began operating. To assess the reliability of the EIA data used in this report, we reviewed documentation from EIA, interviewed relevant officials who were involved in collecting and compiling the data, and conducted electronic testing of the data. We determined that the data were sufficiently reliable for our purposes. Because the EIA data were collected in 2008, we also contacted all 50 states and the District of Columbia and sent a survey to states with tall stacks to determine if any changes had taken place in the number or operating status of stacks since that time. We updated the relevant EIA data with more recent data from our survey results. To determine what is known about tall stacks' contribution to the interstate transport of air pollution, we reviewed reports from EPA and academics and spoke with stakeholders with expertise on this topic. These stakeholders included EPA officials involved in modeling interstate transport of air pollution from power plants, officials from utilities and construction firms that design and build power plants, atmospheric scientists who conduct research on this topic, and state officials who are involved in permitting power plants and complying with federal regulations governing the interstate transport of air pollution. We also analyzed the EIA data to determine the pollution control equipment installed at coal power plants with stacks 500 feet or higher. To determine the number of tall stacks that have been built above their GEP height since 1988, we used survey responses from 22 states in which tall stacks have been built since 1988 to obtain information about the GEP height for these stacks. In this survey, we also asked for reasons that a stack was built above GEP, when applicable. In those cases where state officials could not provide a reason for why a stack was built above its GEP height, we contacted several of the operators of these facilities to obtain this information.

We conducted our work from July 2010 through May 2011 in accordance with all sections of GAO's quality assurance framework that are relevant to our objectives. This framework requires that we plan and perform the engagement to obtain sufficient, appropriate evidence to meet our stated objectives and to discuss any limitations in our work. We believe that the information and data obtained, and the analysis conducted, provide a reasonable basis for any findings and conclusions. A more detailed description of our scope and methodology is presented in appendix I.

Background

The five principal emissions from coal power plants are carbon dioxide, SO_2, NO_x, particulate matter, and mercury. For the purposes of this report, we are focusing on power plants' emissions of SO_2, NO_x, and particulate matter since they, along with ozone, are the focus of a rule currently proposed by EPA—the Transport Rule—which seeks to limit the interstate transport of emissions of SO_2 and NO_x in order to abate violations of particulate matter and ozone NAAQS in downwind states. According to an EPA analysis, as of 2008, power plants emitted over 65 percent of SO_2 emissions and almost 20 percent of NO_x emissions, nationwide. These emissions impact local air quality, but they can also travel hundreds of miles to impact the air quality of downwind states. In developing the Transport Rule, EPA has found that emissions of SO_2 and NO_x from 31 eastern states and the District of Columbia prevent downwind states from meeting NAAQS for ozone and particulate matter. SO_2 and NO_x emissions contribute to the formation of fine particulate matter, and NO_x emissions contribute to the formation of ozone, which can cause or aggravate respiratory illnesses.[3]

EPA began establishing NAAQS for criteria air pollutants in the early 1970s. When the NAAQS began going into effect in the 1970s, tall stacks were built in large numbers as a dispersion technique to help reduce ground-level concentrations of pollutants in the immediate vicinity of the

[3]Ozone is formed through a series of chemical reactions between NO_x; other chemicals in the atmosphere, known as volatile organic compounds; and sunlight. Cars and power plants that burn fossil fuels are contributors of NO_x pollution.

stack. In 1970, there were only 2 stacks higher than 500 feet in the United States, but this number had increased to more than 180 by 1985.

While constructing a tall stack is a dispersion technique that helps to reduce pollution concentrations in the local area, using tall stacks does not reduce total emissions that can potentially be transported to downwind states. The 1977 amendments to the Clean Air Act discouraged the use of dispersion techniques to help attain NAAQS. Specifically, section 123 prohibits states from counting the dispersion effects of stack heights in excess of a stack's GEP height when determining a source's emissions limitation. The Clean Air Act defines GEP as "the height necessary to insure that emissions from the stack do not result in excessive concentrations of any air pollutant in the immediate vicinity of the source as a result of atmospheric downwash, eddies, or wakes which may be created by the source itself, nearby structures, or nearby terrain obstacles."[4] According to federal regulations, a stack's GEP height is the higher of

- 65 meters, measured from the ground-level elevation at the base of the stack;
- a formula based on the height and width of nearby structure(s) (height plus 1.5 times the width or height, whichever is lesser);[5] or
- the height demonstrated by a fluid model or field study that ensures the emissions from a stack do not result in excessive concentrations of any air pollutant as a result of atmospheric downwash created by the source itself, nearby structures, or nearby terrain features.

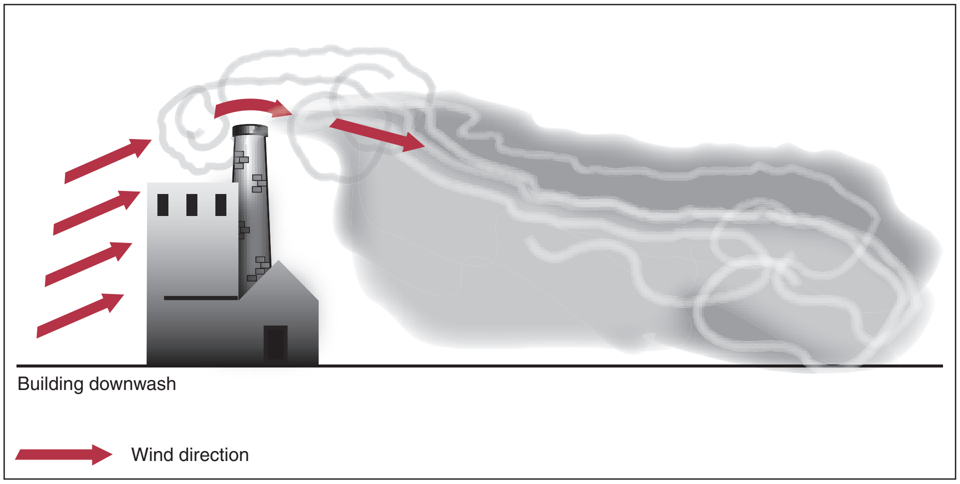
Downwash occurs when large buildings or local terrain distort or impact wind patterns, and an area of more turbulent air forms, known as a wake.

[4]40 U.S.C. § 7423(c) (2006). GEP is a regulatory term used to refer to the minimal height necessary to avoid excessive downwash, but does not necessarily imply that the GEP height is optimized based on structural engineering principles.

[5]For stacks in existence on January 12, 1979, and for which the owner or operator had obtained all applicable permits or approvals, the GEP height formula is 2.5 times the height of nearby structure(s). Structures that are next to one another are considered a single structure if their "distance of separation is less than their smallest dimension (height or width)." See EPA, *Guidelines for Determination of Good Engineering Practice Stack Height* (Research Triangle Park, N.C., 1985).

Emissions from a stack at a power plant can be drawn into this wake and brought down to the ground near the stack more quickly (see fig. 1).

Figure 1: Building Downwash



Source: GAO analysis of EPA information.

States issue air permits to major stationary sources of air pollution, such as power plants, and determine GEP for stacks when they set emissions limitations for these sources. Emissions limitations may be reset when plants undergo New Source Review. New Source Review is a preconstruction permitting program which requires a company that constructs a new facility or makes a major modification to an existing facility to meet new, more stringent emissions limitation based on the current state of pollution control technology. A stack's GEP height is used in air dispersion modeling that takes place when emissions limitations are developed for a source as part of the permitting process.

Many sources contribute to levels of pollution that affect the ability of downwind states to attain and maintain compliance with NAAQS, and some of these pollutants may originate hundreds or thousands of miles from the areas where violations are detected. The Clean Air Act's "good neighbor provisions" under section 110 of the Act require states to prohibit emissions that significantly contribute to nonattainment or interfere with maintenance of NAAQS in downwind states or which will interfere with downwind states' ability to prevent significant deterioration of air quality.[6] Section 126 of the Clean Air Act also allows a downwind state to petition EPA to determine that specific sources of air pollution in upwind states interfere with the downwind state's ability to protect air quality and for EPA to impose emissions limitations directly on these sources. As detailed in the timeline below, Congress granted EPA increased authority to address interstate transport of air pollution under the Clean Air Act, and EPA acted on this authority.

- *1977 amendments to the Clean Air Act*. These amendments contained two provisions that focused on interstate transport of air pollution, the predecessor to the current good neighbor provision of section 110 of the Act and section 126. These amendments also established the New Source Review program.

- *1990 amendments to the Clean Air Act*. These amendments added the Acid Rain Program (Title IV) to the Clean Air Act, which created a cap-and-trade program for SO_2 emissions from power plants, with a goal of reducing annual SO_2 emissions by 10 million tons from 1980 levels and reducing annual NO_x emissions by 2 million tons from 1980 levels by the year 2000.

- *1998 NO_x SIP Call*. After concluding that NO_x emissions from 22 states and the District of Columbia contributed to the nonattainment of NAAQS for ozone in downwind states, EPA required these states to amend their SIPs to reduce their NO_x emissions. EPA took this regulatory action based on section 110 of the Clean Air Act.

- *2005 Clean Air Interstate Rule (CAIR)*. This regulation required SIP revisions in 28 states and the District of Columbia that were found to contribute significantly to nonattainment of NAAQS for fine particulate matter and ozone in downwind states. CAIR required reductions for SO_2 and NO_x emissions from 28 eastern states and the District of Columbia and included an option for states to meet these reductions through regional cap-and-trade programs. When the rule was finalized, EPA estimated it would annually reduce SO_2 and NO_x emissions by 3.8 million and 1.2 million tons, respectively, by 2015. The U.S. Court of Appeals remanded CAIR to EPA in 2008 because it found significant

[6] Prevention of significant deterioration is a standard used to refer to areas of the country which are already in attainment with NAAQS. Sources that are constructed or undergo major modifications in such areas must install the Best Available Control Technology to help prevent the air quality from deteriorating to the level set by NAAQS.

flaws in the approach EPA used to develop CAIR, but allowed the rule to remain in place while EPA develops a replacement rule.

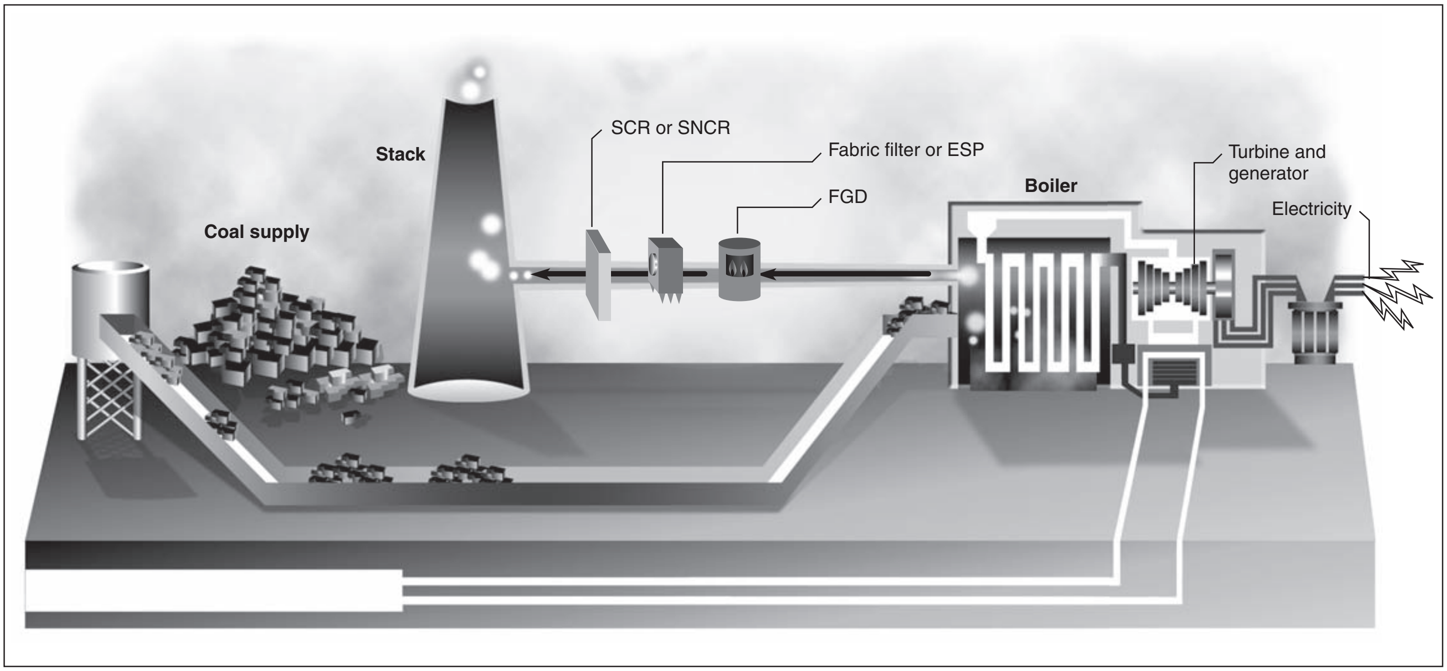
- *2010 Transport Rule*. EPA proposed this rule to replace CAIR, which aims to reduce emissions of SO_2 and NO_x from power plants.[7] If finalized as written, the rule would require emissions of SO_2 to decrease 71 percent over 2005 levels and emissions of NO_x to decrease by 52 percent over 2005 levels by 2014.[8]

As described above, EPA's efforts to address the interstate transport of air pollution from power plants have focused on reducing the total emissions of SO_2 and NO_x from these plants. Unlike tall stacks, pollution controls help to reduce the actual emissions from power plants by either reducing the formation of these emissions or capturing them after they are formed. At coal power plants, these controls are generally installed in either the boiler, where coal is burned, or the duct work that connects a boiler to the stack. A single power plant can use multiple boilers to generate electricity, and the emissions from multiple boilers can sometimes be connected to a single stack. Figure 2 shows some of the pollution controls that may be used at coal power plants: fabric filters or electrostatic precipitators (ESP) to control particulate matter, flue gas desulfurization (FGD) units—known as scrubbers—to control SO_2 emissions, and selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR) units to control NO_x emissions.

[7]EPA believes that the Transport Rule addresses the court's concerns with CAIR by, among other things, introducing a state-specific methodology for identifying significant contributions to nonattainment and interference with maintenance, and proposing remedy options to ensure that all necessary reductions are achieved in the covered states.

[8]In particular, the Transport Rule focuses on helping states attain the 8-hour ozone standard and the particulate matter 2.5 standard. This particulate matter 2.5 standard focuses on particles that are 2.5 micrometers in diameter and smaller, about 1/30th the diameter of a human hair, which have been shown to aggravate respiratory and cardiovascular disease.

Figure 2: Sample Layout of Pollution Controls in a Coal Power Plant



Source: GAO analysis of information from Electric Power Research Institute and Tennessee Valley Authority.

The reduction in emissions from a coal power plant by the use of pollution controls can be substantial, as shown in table 1. The installation of pollution control equipment can also be expensive. According to a Massachusetts Institute of Technology study of coal power plants, it may cost anywhere from $215,000 per megawatt to $330,000 per megawatt to install controls at a coal power plant for particulate matter, SO_2, and NO_x.[9] For a typical coal power plant with a capacity of 500 megawatts, this means that it could cost from $107 million to install these controls at a newly built facility up to $165 million to retrofit these controls at an existing facility. Additionally, pollution controls can require additional energy to operate, known as an energy penalty.

[9]Massachusetts Institute of Technology, *The Future of Coal* (Cambridge, Mass., 2007).

Table 1: Summary of Pollution Control Equipment Used at Coal Power Plants

Pollutant targeted	Control equipment name	How it works	Removal efficiency
Particulate matter	ESP	An induced electrical charge removes particles from flue gas	Capable of 99.0-99.5% removal of particulates
Particulate matter	Fabric filter (commonly referred to as a “baghouse”)	Flue gas passes through a tightly woven fabric filter	Capable of 99.9% removal of particulates
SO_2[a]	FGD unit (commonly referred to as a “scrubber”)	Wet FGDs inject a liquid sorbent, such as limestone, into the flue gas to form a wet solid that can be disposed of or sold Dry FGDs inject a dry sorbent, such as lime, into the flue gas to form a solid by-product that is collected	Wet FGDs – Capable of 80-99% removal of SO_2 Dry FGDs – Capable of 70-95% removal of SO_2
NO_x	Combustion control technologies, such as low-NO_x burners[b]	Coal combustion conditions are adjusted so that less NO_x formation occurs	Capable of 40-45% reduction in the formation of NO_x
NO_x	Post-combustion controls, such as SCR and SNCR units	SCRs inject ammonia into flue gas to form nitrogen and water and use a catalyst to enhance the reaction SNCRs inject ammonia as well, but do not use a catalyst	SCRs – Capable of 70-95% removal of NO_x SNCRs – Capable of 30-75% removal of NO_x

Source: GAO summary of reports by EPA, National Academies, Electric Power Research Institute, and industry documents.

[a]Another approach to reducing SO_2 emissions from a coal power plant is for a plant to switch from using coal with a higher sulfur content to coal with a lower sulfur content, or to blend higher sulfur coal with lower sulfur coal.

[b]Low-NO_x burners can be used in conjunction with post-combustion controls for NO_x as well.

Almost 300 Tall Smokestacks Operate in 34 States, and about Half Began Operating before 1980

According to our analysis of EIA data, which we updated with our survey results, we found a total of 284 tall smokestacks were operating at 172 coal power plants in 34 states, as of December 31, 2010. While about half of the tall stacks began operating more than 30 years ago, there has been an increase in the number of tall stacks that have begun operating in the last 4 years, which several stakeholders attributed to the need for new stacks when retrofitting existing plants with pollution control equipment.

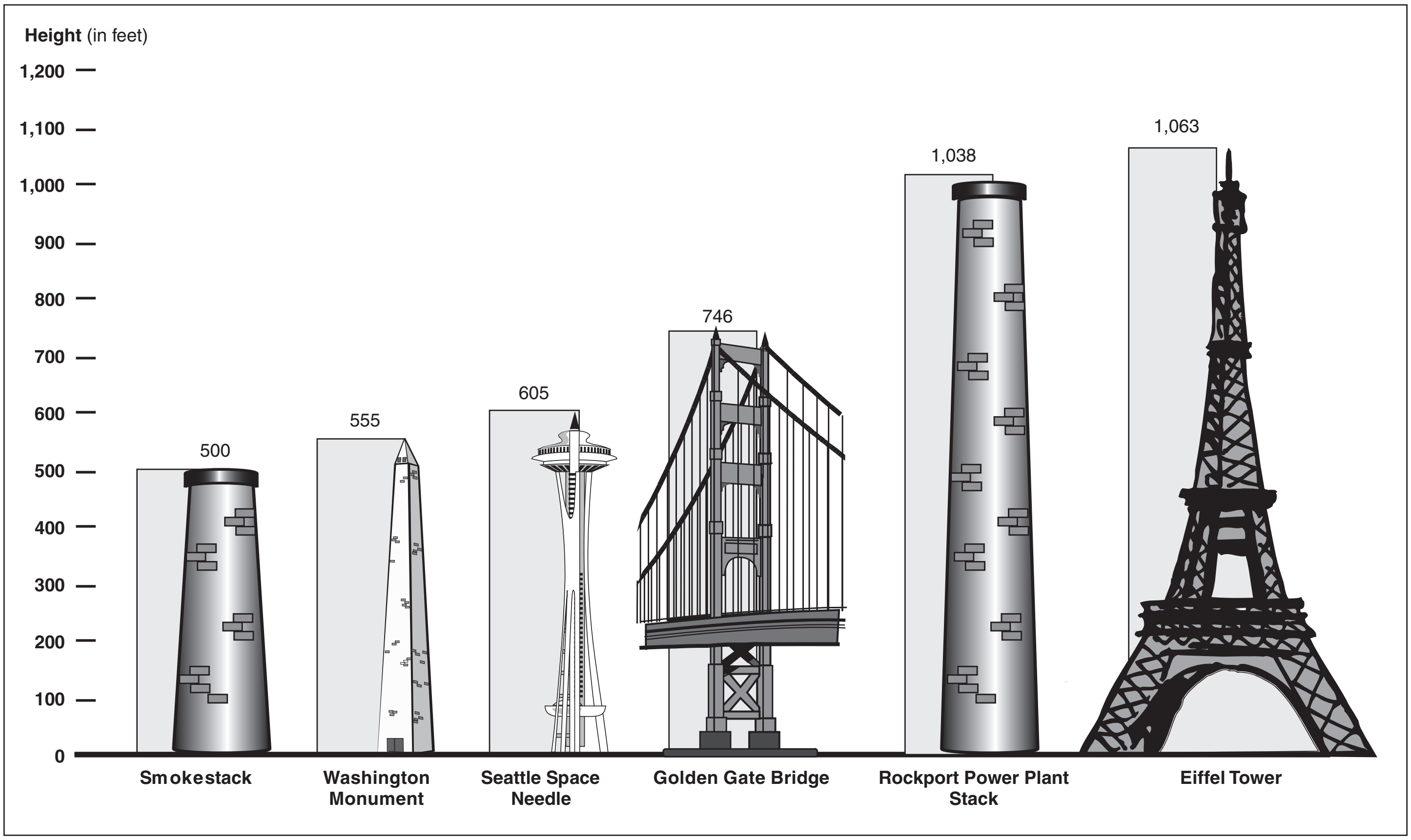
284 Tall Stacks Were Operating at about 170 Coal Power Plants, with Approximately One-Third Located in the Ohio River Valley

As of December 31, 2010, we found a total of 284 tall stacks were operating at 172 coal power plants in the United States. These tall stacks account for about 35 percent of the 808 stacks operating at coal power plants in the United States, and they are generally located at larger power plants. Specifically, we found these stacks are associated with 64 percent of the coal generating capacity.[10]

We found that 207 tall stacks (73 percent) are between 500 and 699 feet tall and that 63 stacks (22 percent) are between 700 and 999 feet tall. The remaining 14 stacks (5 percent) are 1,000 feet tall or higher, with the tallest stack at a coal power plant in the United States having a height of 1,038 feet at the Rockport Power Plant in Indiana. In figure 3, we show how a tall stack compares to the heights of other well-known structures.

[10]For the purposes of this report, our discussion of capacity refers to nameplate capacity, which refers to maximum rated output of electric generating units as designed by the manufacturer.

Figure 3: Comparison of Tall Stacks to Well-Known Structures

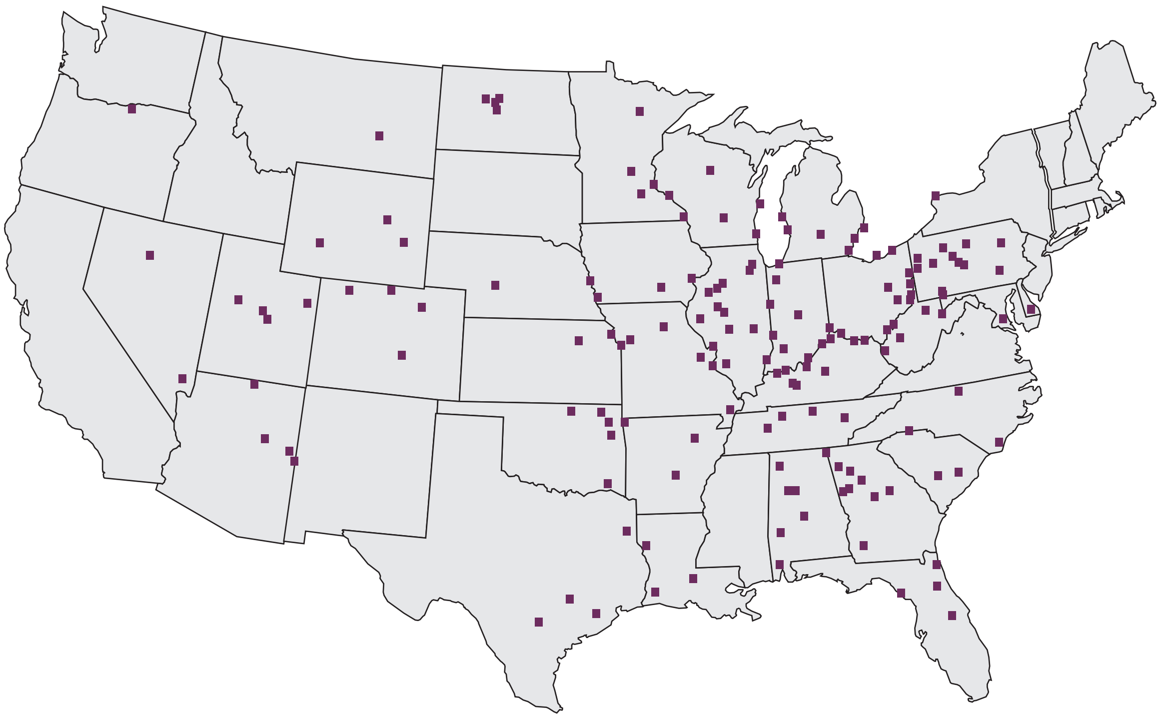


Source: GAO analysis of information for relevant buildings.

Thirty-five percent of the 284 tall stacks are concentrated in 5 states along the Ohio River Valley—Kentucky, Ohio, Indiana, Illinois, and Pennsylvania—at 59 coal power plants. Another 32 percent are located in Alabama, Missouri, West Virginia, Michigan, Georgia, Wyoming, Wisconsin, and Texas, while the remaining 33 percent of tall stacks are located across 21 other states.[11] Figure 4 shows the location of coal power plants with operating tall stacks. For counts of all tall stacks by state, see appendix II.

[11]Percentages may not sum to 100 due to rounding.

Figure 4: Location of Coal Power Plants with Operating Tall Stacks, as of December 2010



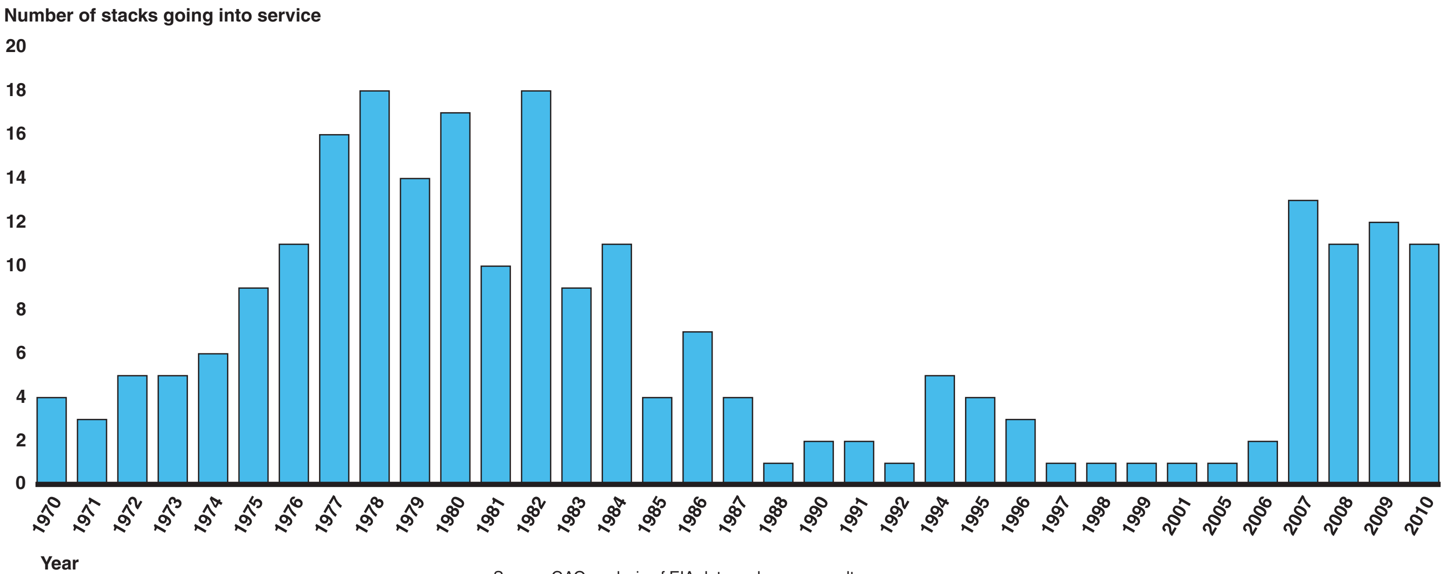
Sources: GAO and Map Resources (map).

Note: Alaska and Hawaii are not included because they do not have tall stacks.

About Half of All Tall Stacks Began Operating before 1980, but an Increasing Number Have Gone into Service in the Last 4 Years

Forty-six percent of the 284 tall stacks operating at coal power plants in the United States as of December 31, 2010, went into service before 1980. Another 28 percent went into service in the 1980s, 7 percent went into service in the 1990s, and 18 percent went into service since 2000. Of the stacks that went into service since 2000, a vast majority went into service in the last 4 years, as shown in figure 5.

Figure 5: Distribution of Operating Tall Stacks by Year Stack Went Into Service



Source: GAO analysis of EIA data and survey results.

A large majority of the tall stacks that went into service in the past 4 years are replacements of existing, older stacks. Several stakeholders told us many of these older stacks were replaced to accommodate changes in flue gas that resulted from the installation of certain types of pollution control equipment to meet emission reductions required by the first phase of CAIR. For example, stakeholders explained that a FGD unit—used to reduce SO_2 emissions—reduces the temperature and increases the moisture of a plant's flue gas.

Stack Height Contributes to Interstate Transport of Air Pollution, and the Emissions from Several Tall Stacks Remain Uncontrolled for Certain Pollutants

Stack height is one of several factors that contribute to the interstate transport of air pollution. While the use of pollution controls has increased in recent years at coal power plants, several boilers connected to tall stacks remain uncontrolled for certain pollutants.[12]

Stack Height Is One of Several Factors that Contribute to the Interstate Transport of Air Pollution

Stack height is one of several factors that contribute to the interstate transport of air pollution. According to reports and stakeholders with expertise on this topic, tall stacks generally disperse pollutants over longer distances than shorter stacks and provide pollutants with more time to react in the atmosphere to form ozone or particulate matter. However, the interstate transport of air pollution is a complex process that involves several variables—such as total emissions from a stack, the temperature and velocity of the emissions, and weather—in addition to stack height. As a result, stakeholders had difficulty isolating the exact contribution of stack height to the interstate transport of air pollution, and we found limited research on this specific topic. For example, EPA staff involved in the modeling of interstate transport told us that it is difficult to determine the different impacts that stacks of varying heights have on the transport of air pollution. According to one atmospheric scientist we spoke with, the interstate transport of air pollution is a complex process and stack height represents just one variable in this process.

Stakeholders struggled to identify the precise impact of tall stacks, due in part to the other factors that influence how high emissions from a stack will rise. The temperature and velocity of a stack's emissions, along with its height, contribute to what is known as an "effective stack height." Effective stack height takes into account not only the height at which emissions are released, but also how high the plume of emissions will rise,

[12]Pollution control equipment is not installed directly on smokestacks. Instead, pollution control equipment is installed throughout a power plant to reduce the formation of pollutants and remove them before they are emitted through the stack.

which is influenced by the temperature and velocity of these emissions. One atmospheric scientist told us the emissions from a shorter stack could rise higher than a taller stack, depending on the temperature and velocity of the emissions.

Weather also plays a key role in the transport of air pollution. A study by the Northeast States for Coordinated Air Use Management (NESCAUM)—a group that represents state air agencies in the Northeast—described weather patterns that can contribute to high-ozone days in the Ozone Transport Region, which includes 12 states in the Mid-Atlantic and New England regions and the District of Columbia.[13] These high-ozone days typically occur in the summer on hot days, when the sun helps transform NO_x and volatile organic compounds into ozone. Wind speeds and wind direction also help to determine how emissions will travel. In the Mid-Atlantic United States, the wind generally blows from west to east during the day, and wind speeds are generally faster at higher elevations. The time of day can also influence the transport of air pollution. According to the NESCAUM report and researchers we spoke with, ozone can travel hundreds of miles at night with the help of high-speed winds known as the low-level jet. This phenomenon typically occurs at night when an atmospheric inversion occurs due to the ground cooling quicker than the upper atmosphere. A boundary layer can form between these two air masses several hundred feet off the ground, which can allow the low-level jet to form and transport ozone and particulate matter with its high winds. As the atmosphere warms the following day, this boundary layer can break down and allow these transported emissions to mix downward and affect local air quality.

Air dispersion models typically take into account stack height along with these other factors when predicting the transport of emissions from power plants. For example, EPA used the Comprehensive Air Quality Model with Extensions (CAMx) to conduct the modeling to support the development of the Transport Rule. CAMx is a type of photochemical grid model, which separates areas into grids and aims to predict the transport of sources that lie within these grids. Key inputs into this model include stack height, the

[13]NESCAUM, *The Nature of the Ozone Air Quality Problem in the Ozone Transport Region: A Conceptual Description* (Boston, Mass., August 2010). The Ozone Transport Region of the eastern United States covers over 62 million people living in Connecticut, Delaware, the District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and northern Virginia.

velocity and temperature of emissions, and weather data.[14] EPA staff involved in conducting this modeling for the Transport Rule said they use the CAMx model to predict the actual impacts of air emissions, and they have not used this model to estimate the specific impact of stack height on interstate transport. They reported their modeling efforts in recent years have been done in support of CAIR and the Transport Rule, and have been focused on modeling the regional impacts of reducing total air emissions.

Several stakeholders we spoke with said total emissions is a key contributor to interstate transport of air pollution, and the use of pollution controls at coal power plants is critical to reducing interstate transport of air pollution. Reducing the total emissions from a power plant influences how much pollution can react in the atmosphere to form ozone and particulate matter that can ultimately be transported.

Use of Pollution Controls at Coal Power Plants Has Increased in Recent Years, but Emissions from Some Plants, Including Several with Tall Stacks, Remain Uncontrolled for Certain Pollutants

The use of pollution control equipment, particularly for SO_2 and NO_x emissions, has increased over time, largely in response to various changes in air regulations, according to stakeholders and reports we reviewed. According to EIA data, the generating capacity of power plants that is controlled by FGDs has increased from about 87,000 megawatts to about 140,000 megawatts from 1997 to 2008.[15] Since coal power plants had about 337,000 megawatts of generating capacity in 2008, this means that about 42 percent of the generating capacity was controlled by a FGD in 2008. Similarly, SCRs were installed at about 44,000 megawatts worth of capacity from 2004 through 2009, with about one-third of these installations occurring in 2009 alone, according to an EPA presentation on this topic. EPA and state officials, along with electric utility officials, told us that the increase in the use of these pollution controls is due to various air regulations, such as the Acid Rain Program and CAIR, which focused on reducing SO_2 and NO_x emissions.

[14]There are also other air models that are used to predict the dispersion of air pollution from specific sources of emissions, such as AERMOD. The data inputs into AERMOD include 5 years of regionally representative meteorological data, emissions rate, and stack parameters (height, velocity, and temperature of emissions).

[15]A megawatt is a unit for measuring the electric generation capacity of a power plant. One megawatt of capacity operating for 1 full day produces 24 megawatt-hours—or 24,000 kilowatt-hours of electricity. According to EIA analysis, the typical American home consumes about 11,040 kilowatt-hours of electricity a year.

However, while we found that the use of pollution controls at coal power plants has increased in recent years, many boilers remain uncontrolled for certain pollutants, including several connected to tall stacks. For example, we found that 56 percent of the boilers attached to tall stacks at coal power plants do not have a FGD to control SO_2 emissions. Collectively, we found that these uncontrolled boilers accounted for 42 percent of the total generating capacity of boilers attached to tall stacks.[16] Our findings on FGDs are similar to EPA data on all coal power plants. In 2009, EPA estimated that 50 percent of the generating capacity of coal power plants did not have FGDs.

For NO_x controls, we found that while about 90 percent of boilers attached to tall stacks have combustion controls in place to reduce the formation of NO_x emissions, a majority of these boilers lack post-combustion controls that can help to reduce NO_x emissions to a greater extent. Specifically, 63 percent of boilers connected to tall stacks do not have post-combustion controls for NO_x, such as SCRs or SNCRs, which help reduce NO_x emissions more than combustion controls alone. Collectively, we found that these boilers without post-combustion controls accounted for 54 percent of the total generating capacity of boilers attached to tall stacks. EPA data on all coal power plants show that 53 percent of the generating capacity for coal power plants did not have post-combustion controls for NO_x emissions in place in 2009.

Tall stacks that had uncontrolled SO_2 and NO_x emissions were generally attached to older boilers that went into service prior to 1980. We found that approximately 85 percent of boilers without FGDs that were attached to tall stacks went into service before 1980. Similarly, over 70 percent of the boilers without post-combustion controls for NO_x went into service before 1980. Overall, we found that about 82 percent of the boilers that lacked both a FGD and post-combustion controls for NO_x went into service before 1980. Some stakeholders attributed the lack of pollution controls on older boilers to less stringent standards that were applied at the time the boilers were constructed. As discussed above, companies that construct a new facility or make a major modification to an existing facility must meet new emissions limitations based on the current state of pollution control technology. Because pollution control technology has

[16]For the purposes of this report, we refer to the capacity of boilers based on information from the EIA-860 form. This form provides capacity for generators that are associated with boilers at power plants.

advanced over time, the standards have become more stringent over time, meaning that boilers constructed before 1980 would have had higher allowable emissions and less need to install controls than boilers constructed in 2010.

Unlike our findings on FGDs and post-combustion controls for NO_x emissions, we found that 100 percent of boilers attached to tall stacks were controlled for particulate matter. However, it is important to note that plants with uncontrolled SO_2 and NO_x emissions contribute to the formation of additional particulate matter in the atmosphere.

Based on Available Information, 17 of 48 Tall Smokestacks Built Since 1988 Exceed Their GEP Height, and A Variety of Factors Can Influence Height Decisions

We identified 48 tall stacks built since 1988 that states reported are subject to the GEP provisions of the Clean Air Act and for which states could provide GEP height information. Of these 48 stacks, we found that 17 exceed their GEP height, 19 are at their GEP height, and 12 are below their GEP height. We found that 15 of the 17 stacks built above GEP were replacement stacks that were built as part of the process of installing pollution control equipment. These stacks vary in the degree to which they exceed GEP height, ranging from less than 1 percent above GEP to about 46 percent above GEP, as shown in table 2. The other 2 stacks built above GEP exceed their GEP height by 2 percent or less.

Table 2: Stacks Built Since 1988 With Heights that Exceed GEP

Plant name and unit number	State	In-service date (year)	Stack height (feet)	GEP height (feet)	Percentage difference between actual and GEP height	Replacement stack?
Bowen (units 3, 4)	Ga.	2008	675	643	5	Yes
Bowen (units 1, 2)	Ga.	2009	675	643	5	Yes
Hammond (units 1, 2, 3, 4)	Ga.	2008	675	464	46	Yes
Wansley (units 1, 2)	Ga.	2008	675	663	2	Yes
Duck Creek (unit 1)	Ill.	2008	588	533	10	Yes
Paradise (unit 3)	Ky.	2006	600	420	43	Yes
Iatan (unit 2)	Mo.	2010	605	604	0.2	Yes
Miami Fort (unit 7)	Ohio	2007	800	705	14	Yes
Miami Fort (unit 8)	Ohio	2007	800	590	36	Yes
WH Sammis (units 1, 2, 3, 4, 5, 6, 7)	Ohio	2010	850	840	1	Yes
Homer City (unit 3)	Pa.	2001	864	853	1	Yes
Montour (units 1, 2)	Pa.	2008	700	540	30	Yes
Brunner Island (unit 3)	Pa.	2009	600	540	11	Yes
Bull Run (unit 1)	Tenn.	2008	500	492	2	Yes
Fayette (unit 3)	Tex.	1988	535	533	0.4	No
JK Spruce (unit 2)	Tex.	2009	601	588	2	No
Mountaineer (unit 1)	W. Va.	2007	1,000	839	19	Yes

Source: GAO analysis of state survey responses.

When we followed up with utility officials regarding why these stacks were built above GEP, they reported that a variety of factors can influence stack height decisions. These factors included helping a plant's emissions clear local geographic features, such as valley walls.[17] According to one state air protection agency, three stacks were built above GEP to provide further protection against downwash. Officials from two utilities said they built stacks above GEP at coal power plants to account for the impact of other structures, such as cooling towers, on the site.[18] Other stakeholders said that utilities may be hesitant to lower stack heights at their facilities when replacing a stack because plant officials have experience with that stack height and its ability to help protect against downwash. An official from one company that builds stacks told us this practice has sometimes occurred because utilities do not want the moisture-rich emissions from the replacement stack to hasten the deterioration of the old stacks, which are usually left in place and must be maintained. In addition, this moisture can create large icicles on the older stacks, which can present a danger to staff working at the power plant.

Other stakeholders highlighted factors that may play a role in making stack height decisions. Some federal and state officials reported that generally there is little incentive to build a stack above GEP because a facility will not receive dispersion credit for the stack's height above GEP. Other stakeholders acknowledged that a stack could be built above GEP for site-specific reasons, such as helping emissions clear nearby terrain features. Some of these officials also noted that cost was another factor considered when making stack height decisions, as it is generally more costly to build a higher stack. For example, one utility official told us that two replacement stacks that were recently built below their original heights could meet their emissions limitations with these lower stack heights because the utility was installing pollution control equipment and did not want to incur the additional cost of building a taller stack.

[17]GEP regulations permit nearby terrain features to be taken into account, but only when determining GEP through the fluid model approach. These terrain features must generally be within 0.5 mile to 2 miles of the source being modeled. If GEP is calculated using only the dimensions of nearby buildings, such nearby terrain features are not part of this calculation. See EPA, *Guidelines for Determination of Good Engineering Practice Stack Height.*

[18]The guidance on determining GEP permits aerodynamic structures such as hyperbolic cooling towers to be taken into account, but only when determining GEP through the fluid model approach. See EPA, *Guidelines for Determination of Good Engineering Practice Stack Height.*

We found that stacks built above GEP since 1988 generally were attached to boilers that had controls in place for SO_2, NO_x, and particulate matter, as shown in table 3. We found similar results for stacks that were built at or below their GEP heights.

Table 3: Information on Pollution Controls for Boilers Attached to Tall Stacks Built Since 1988 for which GEP Information was Available

Stacks	Proportion of attached boilers with a FGD installed for SO_2 emissions	Proportion of attached boilers with combustion controls installed for NO_x emissions	Proportion of attached boilers with post-combustion controls installed for NO_x emissions	Proportion of attached boilers with controls installed for particulate matter
Stacks built above GEP	100%	97%	80%	100%
Stacks built at GEP	82	93	75	100
Stacks built below GEP	100	93	73	100

Source: GAO analysis of EIA data and survey results.

We were unable to obtain GEP height information for an additional 25 stacks that were built since 1988 for two reasons. First, some of these stacks replaced stacks that were exempt from the GEP regulations, according to state officials. Section 123 of the Clean Air Act exempts stack heights that were in existence on or before December 31, 1970, from the GEP regulations; because the exemption applies to stack heights rather than to stacks themselves, it covers both original and replacement stacks.[19] Second, states did not have GEP information readily available for some stacks. According to state officials, they did not set new emissions limits at the time these replacement stacks were built because they were part of pollution control projects and emissions from these plants did not increase. For example, one state reported that GEP could have been calculated decades earlier for the original stacks when emissions limitations were set, and they were unable to locate this information in

[19]The continued exemption of a stack also depends on whether the source using the stack is reconstructed or undergoes a major modification. Section 123 also exempts federal coal-fired power plants which commenced operations before July 1, 1957, and whose stacks were constructed under a contract awarded before February 8, 1974.

response to our request.[20] According to EPA staff we spoke with about this issue, states are not required to conduct a GEP analysis in these instances. While we were unable to obtain GEP information for these stacks, our analysis of the pollution controls installed at boilers connected to these stacks yielded similar results to those stacks for which we did obtain GEP information. Specifically, all of these boilers had controls for SO_2 and particulate matter, and 85 percent had post-combustion controls for NO_x.

Agency Comments

We provided a draft of this report to EPA and DOE for review and comment. Both EPA and DOE stated they had no comments.

As agreed with your office, unless you publicly announce the contents of this report earlier, we plan no further distribution until 30 days from the report date. At that time, we will send copies to the appropriate congressional committees, Secretary of Energy, Administrator of EPA, and other interested parties. In addition, this report will be available at no charge on the GAO Web site at http://www.gao.gov.

If you or your staff have any questions regarding this report, please contact me at (202) 512-3841 or trimbled@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made major contributions to this report are listed in appendix III.

Sincerely yours,

David C. Trimble
Acting Director
Natural Resources and Environment

[20] As we noted earlier, the Clean Air Act began requiring the incorporation of emissions limitations into operating permits in 1990. Prior to the 1990 amendments to the Clean Air Act, information applicable to individual sources, including the source's pollution control obligations, was not collected in a single permit but could be scattered throughout numerous provisions of the SIP. This fact may have contributed to officials' difficulty in finding information on sources for which GEP was calculated at an earlier time.

Appendix I: Scope and Methodology

To identify the number and location of smokestacks at coal power plants that were 500 feet or higher as of December 31, 2010, we analyzed data on power plants from the Department of Energy's (DOE) Energy Information Administration (EIA). We also used these data to determine when these stacks began operating. To determine the reliability of these data, we reviewed documentation from EIA, interviewed relevant officials who were involved in collecting and compiling the data, conducted electronic testing of the data, and we determined that the data were sufficiently reliable for our purposes. Because the EIA data were collected in 2008, we contacted all 50 states and the District of Columbia to determine if they had tall stacks and developed and administered a survey to those 38 states with tall stacks to update the relevant EIA data and determine if any changes had taken place in the number or operating status of stacks since that time.[1] We received e-mail addresses for each state from the Web site of the National Association of Clean Air Agencies, which represents air pollution control agencies in 53 states and territories, and developed a survey that we sent to respondents as an e-mail attachment. Prior to sending out this survey, we pretested the survey with officials from 2 states and revised some of the survey questions based on their input. We received responses to our survey from all 38 states and we sent follow-up questions based on their survey responses to clarify certain responses or to ask for additional information. We updated the relevant EIA data with these survey results to include the most recent information available on tall stacks.

We did not include tall stacks that were used as bypass stacks only in times of maintenance or emergencies in our count of tall stacks. State officials reported that bypass stacks are rarely used and would not be used at the same time as plants' fully operating stacks. Additionally, we defined multi-flue stacks—those with multiple flues running within a single casing—as one stack, as opposed to counting each flue as a separate stack. A state modeling official told us they consider multi-flue stacks as single stacks when conducting dispersion modeling.

For the purposes of this report, we defined tall smokestacks to be those that were 500 feet or higher. In our interviews with stakeholders, several told us they considered 500 feet to be a "tall" stack. Some stakeholders

[1] Our survey of 38 states included some stacks that were at power plants that were not fueled by coal or that were not operating yet. When we restricted our analysis to operating tall stacks at coal power plants, we found that such stacks were operating in 34 states.

said that a typical boiler building at a coal power plant is about 200 feet high. Given that the original formula for good engineering practice (GEP) was 2.5 times height of nearby structures, this would equal about 500 feet. Other stakeholders reported that they considered a stack built above GEP to be "tall."

To determine what is known about tall stacks' contribution to the interstate transport of air pollution, we reviewed reports from the Environmental Protection Agency (EPA) and academics and spoke with stakeholders with expertise on this topic. We conducted a literature search of engineering and other relevant journals on the topic of stack height and interstate transport of air pollution, and we reviewed the limited amount of literature we identified. The stakeholders we interviewed included EPA officials involved in modeling interstate transport of air pollution from power plants, officials from utilities and construction firms that design and build power plants, atmospheric scientists who conduct research on this topic, and state officials who are involved in permitting power plants and complying with federal regulations governing the interstate transport of air pollution. We also analyzed the EIA data and our survey results to determine the pollution control equipment installed at coal power plants with stacks 500 feet or higher. Specifically, we identified the control equipment that was associated with boilers that were attached to tall stacks. Pollution control equipment is not installed on stacks themselves; rather it is installed in the boilers or the ductwork that connect the boiler to a stack. We also interviewed stakeholders to learn about trends in installing pollution control equipment and reviewed relevant reports on this topic.

To determine the number of tall stacks that have been built above their GEP height since 1988, we used our survey to obtain information from state officials about the GEP height for these stacks. Twenty-two states had stacks that were over 500 feet that were built since 1988, and we received survey responses from all of them. In our survey, we also asked for reasons that a stack was built above GEP, when applicable. In cases where state officials could not provide specific reasons, we contacted the utilities that operate the plants with these stacks to obtain this information. Specifically, we contacted utilities that were involved in operating 15 of the 17 stacks that were built since 1988 and exceed GEP height, and we were able to interview utilities operating 12 of these stacks. We did not contact the utilities that operate the other 2 stacks, because the stacks are each less than 2 feet above GEP. We also interviewed companies that design and build power plants to ask about some of the general factors that are considered when deciding on stack height. We focused on stacks built since 1988, because that was the year that EPA's regulations for determining GEP height were largely affirmed by the District of Columbia Court of Appeals. EPA began the process of developing these regulations in the late 1970s, but the final regulations were not issued until 1985. The regulations were then challenged in court and were largely affirmed in 1988.

Finally, we conducted site visits to two coal power plants in Ohio. We selected this state because it contained several coal power plants with tall stacks, including some stacks that were built in 1988 or later. During this visit, we interviewed utility officials that operated these plants, along with state and local officials involved in permitting these plants.

We conducted this work from July 2010 through May 2011 in accordance with all sections of GAO's quality assurance framework that are relevant to our objectives. This framework requires that we plan and perform the engagement to obtain sufficient, appropriate evidence to meet our stated objectives and to discuss any limitations in our work. We believe that the information and data obtained, and the analysis conducted, provide a reasonable basis for any findings and conclusions.

Appendix II: Distribution of Tall Stacks by State

Table 4 provides counts of the number of stacks 500 feet or higher—tall stacks—by state. In addition, the table provides information on the generating capacity of the boilers attached to these stacks.

Table 4: Number of Tall Stacks at Coal Power Plants by State and Associated Generating Capacity of Boilers Attached to These Stacks

State	Number of tall stacks	Generating capacity (megawatts)
Ohio	22	19,626
Kentucky	22	14,491
Indiana	19	14,286
Illinois	19	11,824
Pennsylvania	17	15,765
Alabama	14	11,664
Missouri	12	9,360
West Virginia	12	13,920
Michigan	12	8,971
Georgia	11	13,793
Texas	11	9,277
Wyoming	10	4,486
Wisconsin	10	5,264
Arizona	9	4,704
Colorado	8	3,820
Utah	7	4,608
Oklahoma	7	4,112
Florida	7	5,720
Minnesota	6	4,395
Tennessee	6	6,292
North Dakota	6	2,997
Louisiana	5	3,207
Kansas	5	3,738
Iowa	4	3,187
Montana	4	2,272
North Carolina	4	3,404
Arkansas	3	3,958
Nebraska	3	2,014
South Carolina	3	1,564
Nevada	2	572
Delaware	1	164

State	Number of tall stacks	Generating capacity (megawatts)
Oregon	1	601
Maryland	1	728
New York	1	655
Total	**284**	**215,439**

Source: GAO analysis of EIA data and survey results.

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

David C. Trimble, (202) 512-3841 or trimbled@gao.gov

Staff Acknowledgments

In addition to the individual named above, key contributors to this report include Barbara Patterson (Assistant Director), Scott Heacock, Beth Reed Fritts, and Jerome Sandau. Important assistance was also provided by Antoinette Capaccio, Cindy Gilbert, Alison O'Neill, Madhav Panwar, and Katherine Raheb.

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