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Washington, DC 20548

April 18, 2012

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

Subject: *Air Emissions and Electricity Generation at U.S. Power Plants*

Dear Mr. Chairman:

The United States depends on a variety of fuels to generate electricity, including fossil fuels (coal, natural gas, and oil), nuclear power, and renewable sources. Power plants that burn fossil fuels provide about 70 percent of U.S. electricity, but they also produce substantial amounts of harmful air emissions.[1] In particular, electricity generating units at fossil fuel power plants are among the largest emitters of sulfur dioxide and nitrogen oxides, which have been linked to respiratory illnesses and acid rain, as well as of carbon dioxide, the primary greenhouse gas contributing to climate change.[2] Of the three fossil fuels, coal is the most widely used fuel in the United States, providing about 45 percent of electricity in 2010, followed by natural gas, which provided about 24 percent.[3] Coal plays a critical role in the reliability of the electricity grid, especially in certain geographic areas, but coal-fired units also generally emit more air pollution than units burning natural gas or oil.

Under the Clean Air Act, the Environmental Protection Agency (EPA) establishes national ambient air quality standards for six pollutants that states are primarily responsible for attaining.[4] States attain these standards, in part, by regulating emissions of these pollutants from certain stationary sources, such as electricity generating units. Numerous Clean Air Act requirements apply to electricity generating units, including New Source Review (NSR), a permitting process

[1]Fossil fuels are responsible for nearly all emissions of carbon dioxide, sulfur dioxide, and nitrogen oxides from power plants.

[2]An electricity generating unit consists of any combination of an electricity generator, reactor, boiler, combustion turbine, or other equipment operated together to produce electrical power. A power plant is a facility with one or more generating units, together with other equipment used to produce electric power.

[3]Oil is used to a very limited extent, providing less than 1 percent of electricity in 2010.

[4]EPA has set national ambient air quality standards for six pollutants, termed "criteria" pollutants: carbon monoxide, lead, nitrogen oxides, ozone, particulate matter, and sulfur oxides.

established in 1977.[5] Under NSR, owners of generating units must obtain a preconstruction permit that establishes emission limits and requires the use of certain pollution control technologies. NSR applies to (1) generating units built after August 7, 1977, and (2) to existing generating units—regardless of the date built—that seek to undertake a "major modification," a physical or operational change that would result in a significant net increase in emissions of a regulated pollutant. Units built before August 7, 1977, are not required to undergo NSR unless they undertake a major modification. For the purposes of this report, we refer to units that began operation in or before 1978—the first full year after NSR was established—as "older units" and those that began operating after 1978 as "newer units."[6]

In limiting NSR's requirements to facilities built or undertaking major modifications after August 7, 1977, Congress allowed existing facilities to defer installation of pollution controls until they made a major modification, with the expectation that over time all facilities would either install such equipment or shut down, thereby lowering overall emissions. According to EPA data, 1,485 older units (43 percent of fossil fuel units) were still in operation in 2010. Some research suggests that many of these older units continue to operate without emissions controls, and in June 2002, we reported that older fossil fuel electricity generating units emitted air pollution at higher rates than newer units.[7]

This report responds in part to your request for information on electricity generation and emissions at U.S. electricity generating units and the implementation of NSR. Our objective is to provide information on how older fossil fuel electricity generating units compare with newer units in terms of their air emissions and electricity generation. To respond to this objective, we reviewed selected data elements in the Ventyx Velocity Suite EV Market-Ops database. This proprietary database contains consolidated energy and emissions data from EPA, the Energy Information Administration (EIA), and other sources. Specifically, we analyzed how older plants compare with newer plants in their emissions, energy production, location, and fuel type. We reviewed energy and emissions data from calendar year 2010. We reviewed data from units that (1) listed a fossil fuel (coal, natural gas, or oil) as a primary fuel; (2) generated electricity in 2010; and (3) had a net summer capacity greater than 25 megawatts, making them subject to EPA emissions monitoring and reporting requirements. In all, we examined the characteristics of 3,443 electricity generating units—1,485 older units and 1,958 newer units. We focused our analysis on power plant emissions of three regulated pollutants: sulfur dioxide (as a proxy for sulfur oxides), nitrogen oxides, and carbon dioxide (a greenhouse gas).[8] To assess the reliability of the Ventyx data, we reviewed existing documentation about the data and the system that produced them, interviewed Ventyx staff who were knowledgeable about the data,

[5]This report focuses solely on fossil fuel electricity generating units, although NSR also applies to certain other major stationary sources of air pollution, such as other industrial facilities.

[6]We used 1978 as the cutoff date for our analysis—instead of August 7, 1977—because 1978 was the first full year after NSR's establishment, and our analysis reports only annual data.

[7]GAO, *Air Pollution: Emissions from Older Electricity Generating Units*, GAO-02-709 (Washington, D.C.: June 12, 2002). Note: This report defines "older units" as those fossil fuel generating units that began operation before 1972.

[8]Regulated pollutants are sulfur oxides; nitrogen oxides; other criteria pollutants; and, since January 2, 2011, greenhouse gases.

and consulted with EPA and EIA agency officials knowledgeable in energy issues. We determined the Ventyx data to be sufficiently reliable for the purpose of this report.

We conducted this performance audit from February 2012 to April 2012 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Results in Brief

Older electricity generating units—those that began operating in or before 1978—provided 45 percent of electricity from fossil fuel units in 2010 but produced a disproportionate share of emissions, both in aggregate and per unit of electricity generated. Overall, in 2010 older units contributed 75 percent of sulfur dioxide emissions, 64 percent of nitrogen oxides emissions, and 54 percent of carbon dioxide emissions from fossil fuel units. For each unit of electricity generated, older units collectively emitted about 3.6 times as much sulfur dioxide, 2.1 times as much nitrogen oxides, and 1.3 times as much carbon dioxide as newer units. The difference in emissions between older units and their newer counterparts may be attributed to a number of factors. First, 93 percent of the electricity produced by older fossil fuel units in 2010 was generated by coal-fired units. Compared with natural gas units, coal-fired units produced over 90 times as much sulfur dioxide, twice as much carbon dioxide and over five times as much nitrogen oxides per unit of electricity, largely because coal contains more sulfur and carbon than natural gas. Second, fewer older units have installed emissions controls, which reduce emissions by limiting their formation or capturing them after they are formed. Among coal-fired units—which produce nearly all sulfur dioxide emissions from electric power generation—approximately 26 percent of older units used controls for sulfur dioxide, compared with 63 percent of newer units. Controls for nitrogen oxide emissions were more common among all types of fossil fuel units, but these controls vary widely in their effectiveness. Among older units, 14 percent had installed selective catalytic reduction (SCR) equipment, the type of control capable of reducing the greatest amount of nitrogen oxides emissions, compared with 33 percent of newer units. In addition, approximately 38 percent of older units did not have any controls for nitrogen oxides, compared with 6 percent of newer units. Third, lower emissions among newer units may be attributable in part to improvements in the efficiency with which newer units convert fuel into electricity. Nonetheless, older units remain an important part of the electricity generating sector, particularly in certain regions of the United States.

Background

The efficient and reliable operation of the electricity industry is critical to the health of the U.S. economy. Residential consumers rely on electricity to power their households, and electricity is a key input for businesses that produce trillions of dollars in products and services. Domestic energy production also provides U.S. jobs and supports economic growth. Plentiful, reliable, and relatively inexpensive fossil fuels have been a mainstay of the U.S. electricity mix.

The electricity generating sector is also a major contributor to air emissions in the United States. Based on emissions data published by EPA, in 2010, fuel combustion by electric utilities was responsible for about 65 percent of sulfur dioxide emissions and 16 percent of nitrogen oxides

emissions from all sources nationwide.[9] Electricity generation was also responsible for 39 percent of carbon dioxide emissions from all sources in 2009.[10] Units in the Southeast, South Central, and Great Lakes regions produced most of the electricity and emissions from fossil fuel units. (See encls. I through IV for additional information on the location of generating units, their electricity production, and their emissions.)

As we have previously reported, sulfur dioxide and nitrogen oxides have been linked to a variety of health and environmental concerns, and carbon dioxide has been linked to climate change.[11] For example, sulfur dioxide and nitrogen oxides contribute to the formation of fine particles, and nitrogen oxides contribute to the formation of ozone.[12] Fine particles have been linked to premature death, aggravated asthma, and chronic bronchitis, and ozone can inflame lung tissue and increase susceptibility to bronchitis and pneumonia. In addition to affecting health, sulfur dioxide and nitrogen oxides reduce visibility and contribute to acid rain, which harms aquatic life and degrades forests. These emissions affect local air quality, and they can also travel hundreds of miles to affect the air quality of downwind states. In addition, the accumulation of carbon dioxide in the atmosphere is linked to increases in air and ocean temperatures, which could threaten coastal areas with rising sea levels, alter agricultural productivity, and increase the intensity and frequency of floods and tropical storms.

Emissions controls can help reduce the emissions from generating units by either limiting their formation or capturing them after they are formed.[13] At coal-fired units, emissions controls are generally installed in a boiler, where coal is burned, or the duct work that connects the boiler to a smokestack. Figure 1 shows some of the pollution controls that may be used at coal power plants, including flue gas desulfurization units—known as scrubbers—to control sulfur dioxide emissions, fabric filters or electrostatic precipitators to control particulate matter, and selective catalytic reduction (SCR) or selective noncatalytic reduction (SNCR) units to control nitrogen oxides emissions. According to a 2010 EPA report, the development of effective and commercially viable carbon dioxide controls for coal-fired electricity generating units has received significant attention, but some of these technologies are still in the research and development phase, and most are not yet commercially viable.[14]

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[9]EPA, *National Emissions Inventory Air Pollutant Emissions Trends Data*, "Current Emissions Trends Summaries," accessed October 2011, http://www.epa.gov/ttn/chief/trends/index.html#tables.

[10]EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009,* EPA-430-R-11-005 (Washington, D.C.: Apr. 15, 2011).

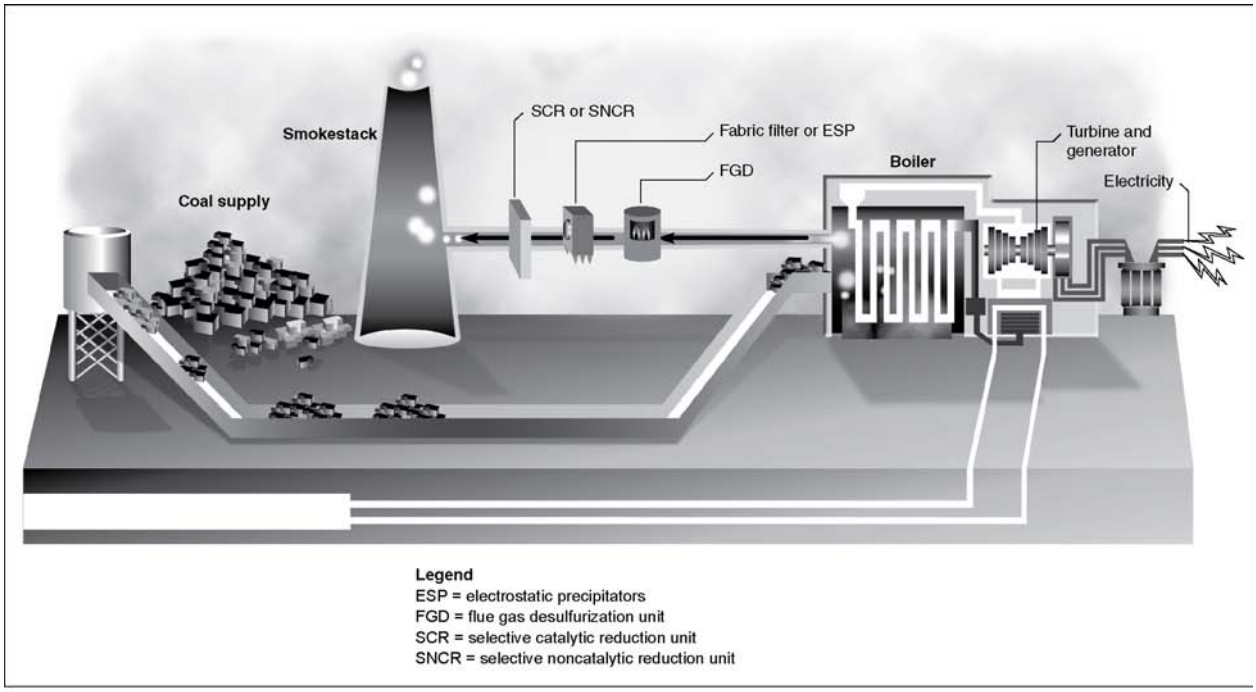
[11]GAO-02-709 and GAO, *Air Quality: Information on Tall Smokestacks and Their Contribution to Interstate Transport of Air Pollution*, GAO-11-473 (Washington, D.C.: May 11, 2011).

[12]Sulfur dioxide and nitrogen oxides can transform into fine particles in the atmosphere. Fine particles are a subset of particulate matter, a regulated pollutant. Ozone, also a regulated pollutant, forms when nitrogen oxides react with volatile organic compounds (chemicals that are emitted as gases from natural sources, such as trees, as well as from anthropogenic sources, such as motor vehicles) in the presence of heat and sunlight.

[13]GAO-11-473.

[14]EPA, Office of Air and Radiation, *Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Coal-Fired Electric Generating Units* (Research Triangle Park, NC: October 2010).

Figure 1: Sample Layout of Emissions Controls at a Coal Power Plant



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

The reduction in emissions from the use of emissions controls can be substantial, as shown in table 1. Used commercially since the early 1970s, scrubbers are the most common technology for reducing sulfur dioxide emissions, and are capable of removing up to 99 percent of sulfur dioxide emissions. Commercially available low-nitrogen-oxide burners and SCRs are among the more common nitrogen oxide control technologies, with SCRs able to reduce these emissions by more than 90 percent. The installation of emissions controls can also be expensive. According to EPA, a typical coal unit with a capacity of 700 megawatts could incur from $269 million to $329 million to install a scrubber and from $108 million to $129 million to install an SCR, plus operating and maintenance costs.[15] Additionally, emissions controls can require additional electricity from the unit to operate, which reduces the amount of electricity available to be used by customers.

[15]EPA, *Integrated Planning Model,* "TR Base Case v.4.10," accessed April 2, 2012, http://www.epa.gov/airmarkets/progsregs/epa-ipm/BaseCasev410.html#documentation.

Table 1: Summary of Emissions Control Equipment Used at Electricity Generating Units

Pollutant	Control equipment	How it works	Removal efficiency
Sulfur dioxide[a]	Flue gas desulfurization unit (commonly referred to as a "scrubber")	Wet flue gas desulfurization units inject a liquid sorbent, such as limestone, into the flue gas to form a wet solid that can be disposed of or sold. Dry flue gas desulfurization units inject a dry sorbent, such as lime, into the flue gas to form a solid by-product that is collected and removed.	Wet flue gas desulfurization units can remove 80-99 percent of sulfur dioxide. Dry flue gas desulfurization units can remove 70-95 percent of sulfur dioxide.
Nitrogen oxides	Combustion control technologies, such as low-nitrogen-oxides burners[b]	Coal combustion conditions are adjusted to inhibit the formation of nitrogen oxides.	These technologies can reduce formation of nitrogen oxides by 40-45 percent.
	Postcombustion controls, such as selective catalytic reduction and selective noncatalytic reduction units	Selective catalytic reduction units inject ammonia into flue gas to form nitrogen and water and use a catalyst to enhance the reaction. Selective noncatalytic reduction units also inject ammonia but do not use a catalyst.	Selective catalytic reduction units can remove 70-95 percent of nitrogen oxides. Selective noncatalytic reduction units can remove 30-75 percent of nitrogen oxides.

Source: GAO.

[a]Another approach to reducing sulfur dioxide emissions from a coal-fired electricity generating unit 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-nitrogen-oxides burners can be used in conjunction with postcombustion controls for nitrogen oxides.

Older Fossil Fuel Units Produce More Emissions and Less Electricity Than Newer Units

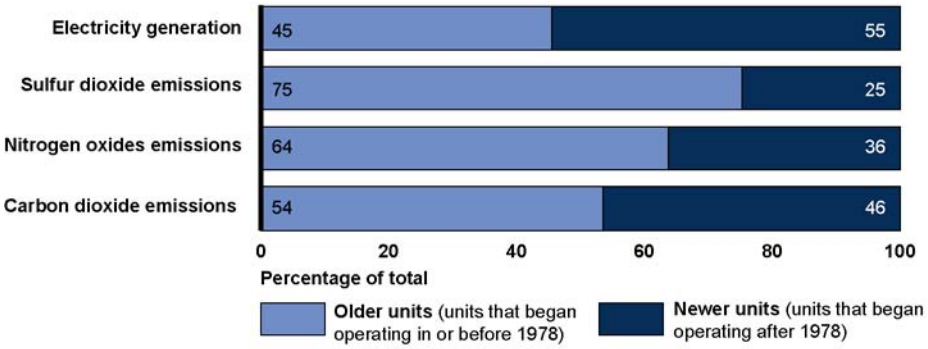
In general, older electricity generating units, which run primarily on coal, produce more emissions than newer units, and at higher rates per unit of electricity. Much of this difference can likely be attributed to a greater reliance on coal among older units. In addition, fewer older units have installed emissions controls, and older units are generally less efficient at converting fuel to electricity. Nonetheless, some older units play an important role in providing reliable electricity to certain U.S. regions.

Older Units Emit More Than Newer Units

In 2010, older fossil fuel electricity generating units—those that began operating in or by 1978—produced a disproportionate share of emissions for the electricity they produced. Specifically, older units generated 45 percent of the electricity from fossil fuel units in 2010 but emitted 75 percent of sulfur dioxide emissions, 64 percent of nitrogen oxides emissions, and 54 percent of carbon dioxide emissions (see fig. 2). Units that began operating after 1978 were responsible for the remainder of the emissions and electricity production.[16]

[16]Of the 3,443 fossil fuel electricity generating units we assessed, 1,485 were older units, and 1,958 were newer units.

Figure 2: Share of Total Electricity and Emissions per Unit of Electricity Generated by Fossil Generating Units in 2010

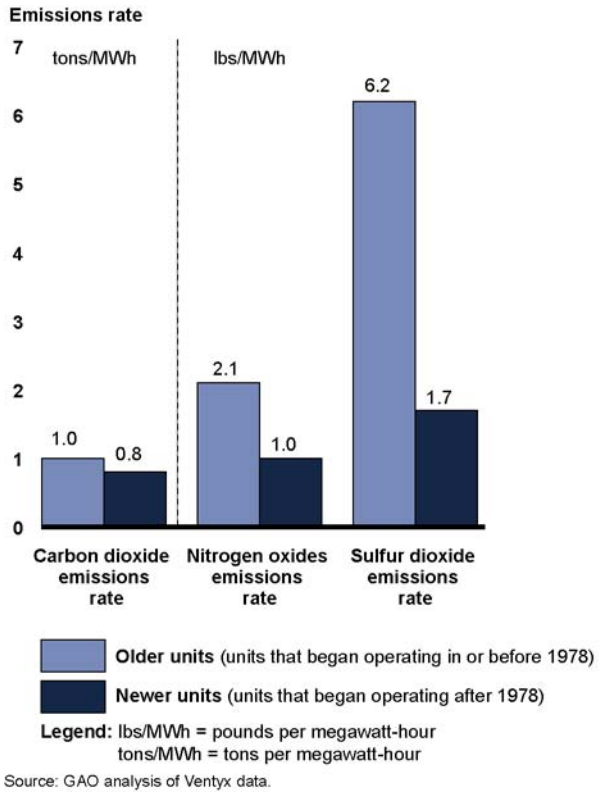


Source: GAO analysis of Ventyx data.

Note: Chart reflects older and newer generating units that use coal, natural gas, and oil. Older generating units are mostly coal fired, whereas newer generating units rely more heavily on natural gas.

Older units produced emissions at a higher rate than newer units in 2010; that is, they produced more emissions per unit of electricity they generated. As shown in figure 3, for each megawatt-hour of electricity generated, older units, on average, emitted about 3.6 times as much sulfur dioxide as newer units, about 2.1 times as much nitrogen oxides, and about 1.3 times as much carbon dioxide.

Figure 3: Emissions per Unit of Electricity Generated in 2010

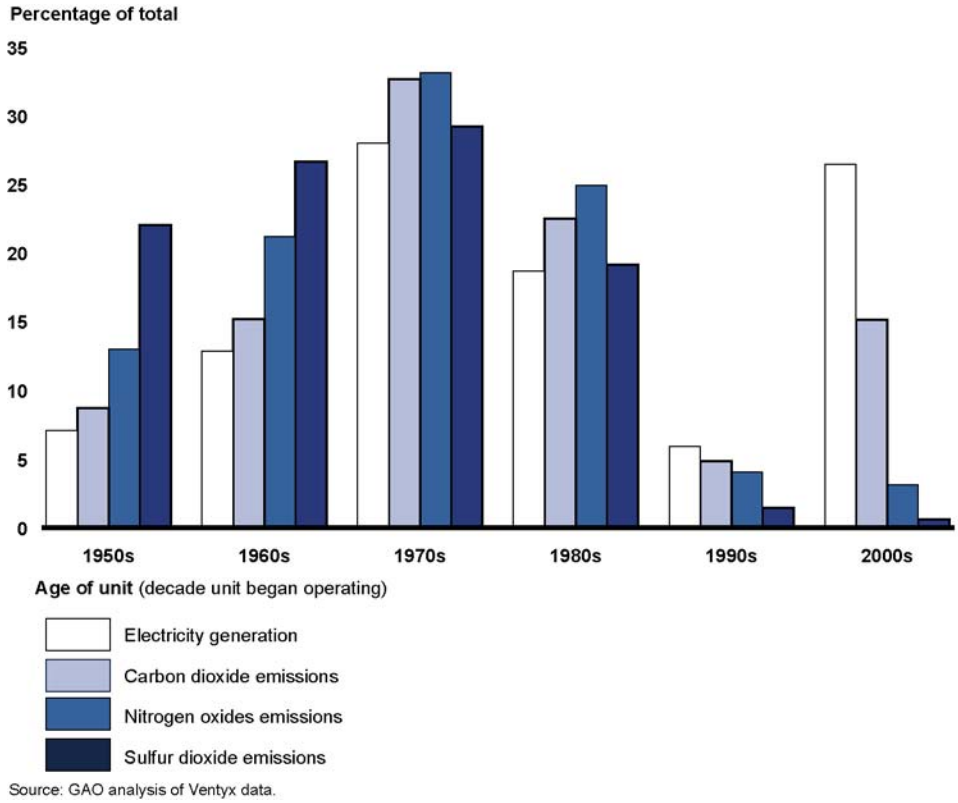


Source: GAO analysis of Ventyx data.

Note: Chart reflects older and newer generating units that use coal, natural gas, and oil. Older generating units are mostly coal-fired, whereas newer generating units rely more heavily on natural gas.

Emissions from fossil fuel units in 2010 varied widely, depending on the decade in which the unit began operating. In aggregate, the oldest units produced the most emissions, and more recently built units produced the least emissions (see fig. 4). For example, units that began operating in the 1960s generated 12 percent of electricity in 2010, but also produced 26 percent of sulfur dioxide emissions, 21 percent of nitrogen oxides emissions, and 15 percent of carbon dioxide emissions in that year. In comparison, units that began operating in the 2000s produced over twice as much electricity (26 percent) in 2010, but a much lower share of emissions—1 percent of sulfur dioxide, 3 percent of nitrogen oxides, and 15 percent of carbon dioxide.

Figure 4: Share of Total Electricity and Emissions Produced by Fossil Fuel Generating Units in 2010, by Decade Unit Began Operating

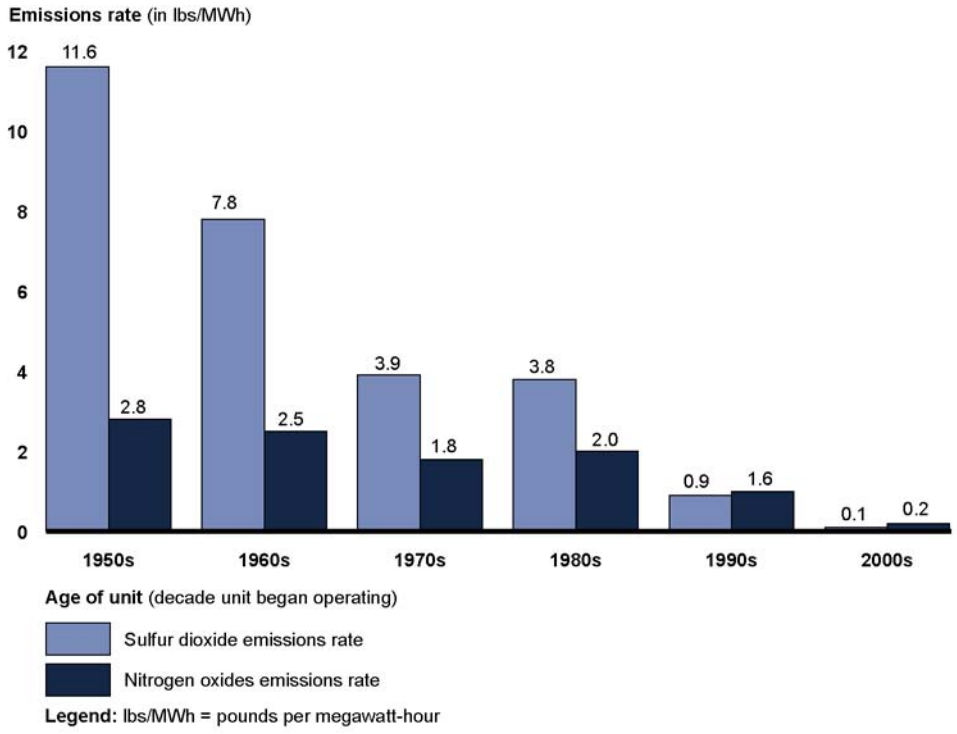


Source: GAO analysis of Ventyx data.

Note: Chart reflects generating units that use coal, natural gas, and oil. Older generating units are mostly coal-fired, whereas newer generating units rely more heavily on natural gas.

As shown in figure 5, units that began operating more recently are more likely to have comparatively lower emissions rates. In 2010, units that began operating in the 1970s or later generally emitted substantially less sulfur dioxide and nitrogen oxides for each unit of electricity they generated. For example, units built in the 1960s emitted an average of of 7.8 pounds of sulfur dioxide and 2.5 pounds of nitrogen oxides per megawatt-hour of electricity generated, whereas units built in the 2000s emitted an average of 0.1 pounds of sulfur dioxide and 0.2 pounds of nitrogen oxides per megawatt-hour.

Figure 5: Emissions of Sulfur Dioxide and Nitrogen Oxides per Unit of Electricity Generated by Fossil Fuel Generating Units in 2010, by Decade Unit Began Operating

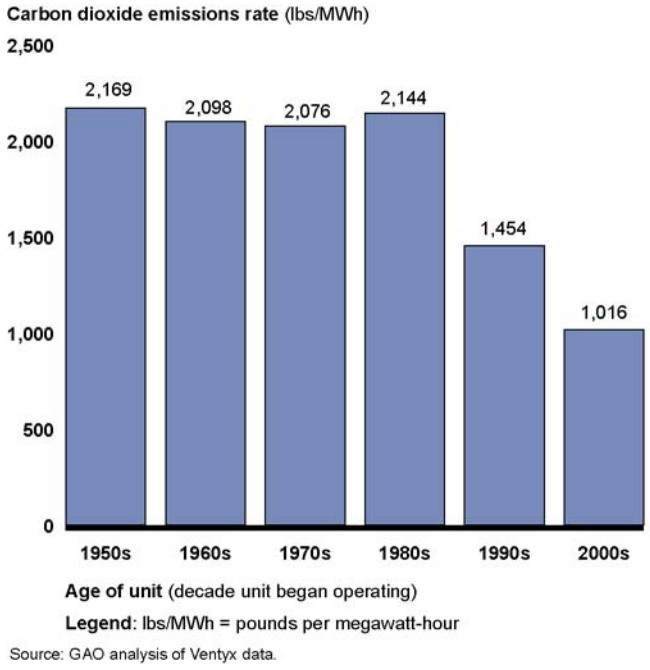


Source: GAO analysis of Ventyx data.

Note: Chart reflects generating units that use coal, natural gas, and oil. Older generating units are mostly coal-fired, whereas newer generating units rely more heavily on natural gas.

Carbon dioxide emissions rates have also declined among newer units in the last several decades, although to a smaller extent. As shown in figure 6, units that began operating in the 1980s emitted an average of 2,160 pounds of carbon dioxide per unit of electricity in 2010, a decline of around one percent compared to units that began operating in the 1950s. In contrast, units that began operating after the 1980s had substantially lower carbon dioxide emissions rates, on average. For example, units that began operating in the 2000s emitted carbon dioxide at a rate of 1,016 pounds per megawatt-hour, about 53 percent less than units that began operating in the 1980s.

Figure 6: Carbon Dioxide Emissions per Unit of Electricity Generated by Fossil Fuel Generating Units in 2010, by Decade Unit Began Operating



Source: GAO analysis of Ventyx data.

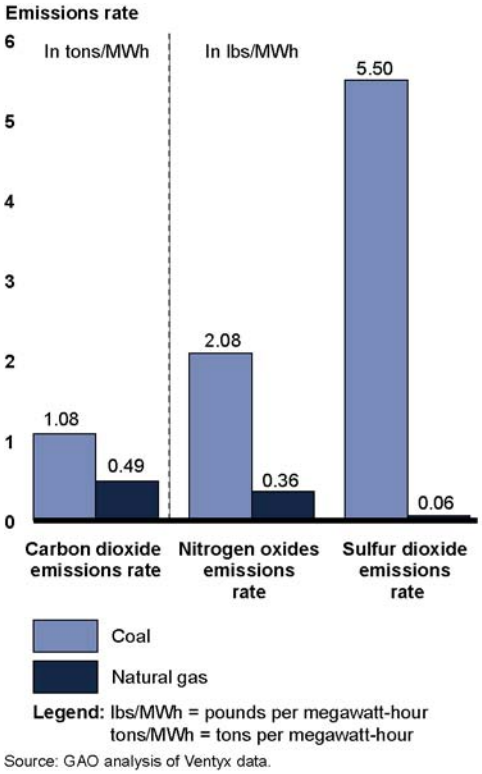
Note: Chart reflects generating units that use coal, natural gas, and oil. Older generating units are mostly coal-fired, whereas newer generating units rely more heavily on natural gas.

As discussed below, we identified three reasons why older units may emit more than newer units: (1) older units are more likely to use coal, (2) older units are less likely to have installed emissions controls, and (3) older units are generally less efficient.

Older Units Are Mostly Fueled by Coal, and Newer Units Rely More on Natural Gas

The difference in emissions between older and newer units is likely due, in part, to significant changes in the fuels used to generate electricity—in particular, a shift from coal to natural gas. Compared with coal, natural gas produces substantially lower emissions per unit of electricity generated, largely because natural gas contains less sulfur and carbon. This disparity is most apparent with sulfur dioxide emissions, as shown in figure 7. On average, coal-fired units—both older and newer—produced over 90 times as much sulfur dioxide emissions per unit of electricity as natural gas-fired units in 2010. Compared to natural gas-fired units, coal-fired units also produced over twice as much carbon dioxide and over five times as much nitrogen oxides per unit of electricity in 2010.

Figure 7: Emissions per Unit of Electricity Generated by Fossil Fuel Generating Units in 2010, by Type of Fuel



Source: GAO analysis of Ventyx data.

Older generating units are much more likely than newer units to use coal as a primary fuel. In 2010, coal-fired units accounted for about 93 percent of electricity from older units and 47 percent of electricity from newer units. While other fossil fuels, particularly oil, played an important role in electricity generation in the late 1960s and 1970s, many of these units have since been retired, a development likely attributable to rising oil prices.[17] In addition, between 1978 and 1987, the Powerplant and Industrial Fuel Use Act of 1978 (Fuel Use Act) restricted construction of new power plants using oil or natural gas as a primary energy source.

Since the 1990s, natural gas has played a much larger role in electricity generation (see fig. 8). After the 1987 repeal of provisions in the Fuel Use Act, use of natural gas by the electric power sector increased by more than 240 percent.[18] As we have previously reported, factors contributing to the rise of natural gas include the comparatively low levels of emissions produced by natural gas units and a long period of low natural gas prices in the 1990s.[19] After rising in the early 2000s, natural gas prices have again fallen in recent years, a trend that may

[17]In 2010, oil-fired units (both older and newer) accounted for less than one percent of electricity from fossil fuel units.

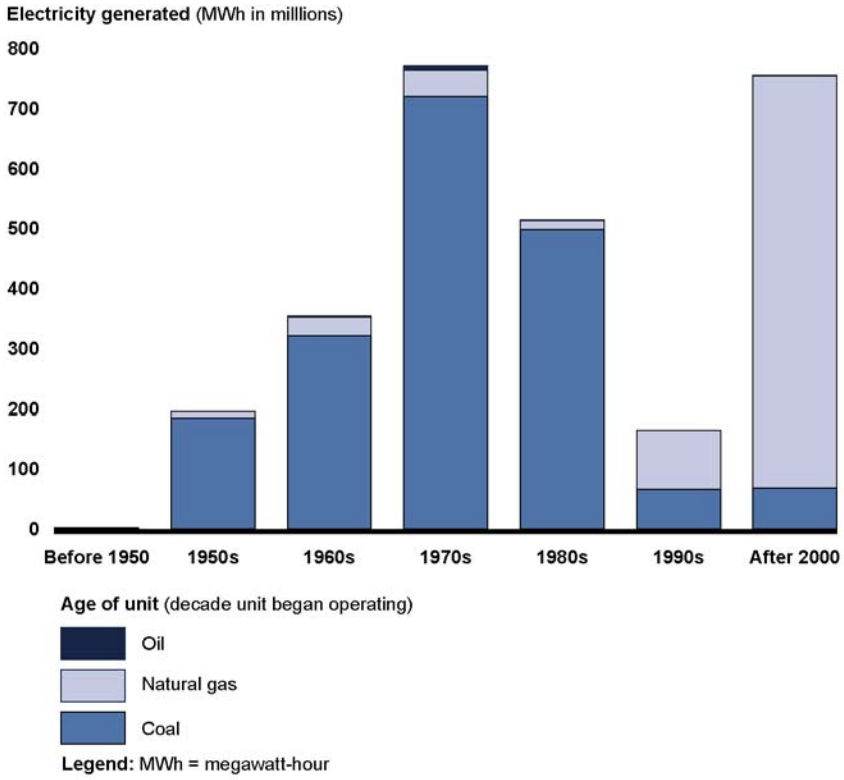
[18]The 240 percent increase refers to 1987 through 2009. See Energy Information Administration, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, D.C.: October 2011).

[19]GAO, *Natural Gas: Factors Affecting Prices and Potential Impacts on Consumers*, GAO-06-420T (Washington, D.C.: Feb. 13, 2006).

influence decisions about the future composition of the fleet of generating units, with the potential for retirements of older coal-fired units and the construction of new natural gas units.

In 2010, natural gas units accounted for approximately one-third of the electricity generated by fossil fuel units. Most of this natural-gas-based generation—about 78 percent—came from units that began operating in 2000 or later. Conversely, most coal-based generation—about 66 percent—came from units that have been operating more than 30 years.

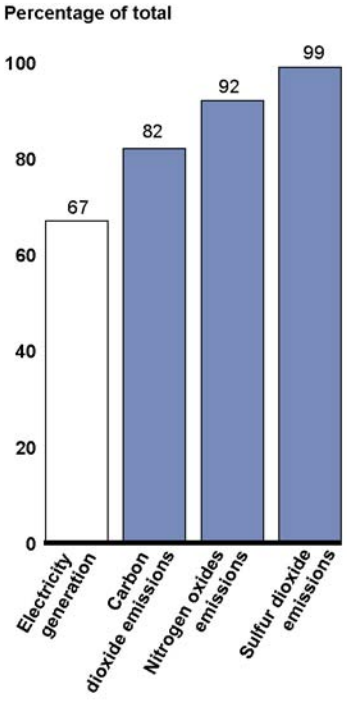
Figure 8: Electricity Generation from Fossil Fuel Generating Units in 2010, by Decade Unit Began Operating and Fuel Type



Source: GAO analysis of Ventyx data.

Nonetheless, coal-fired units, both older and newer, remain both a key source of electricity and a significant source of emissions. As shown in figure 9, coal-fired units generated 67 percent of electricity from fossil fuel units in 2010, but also produced 99 percent of sulfur dioxide emissions, 92 percent of nitrogen oxides emissions, and 82 percent of carbon dioxide emissions from fossil fuel units in that year.

Figure 9: Electricity Generation and Emissions from Coal-Fired Units in 2010, as a Percentage of Total Generation and Emissions from Fossil Fuel Generating Units



Source: GAO analysis of Ventyx data.

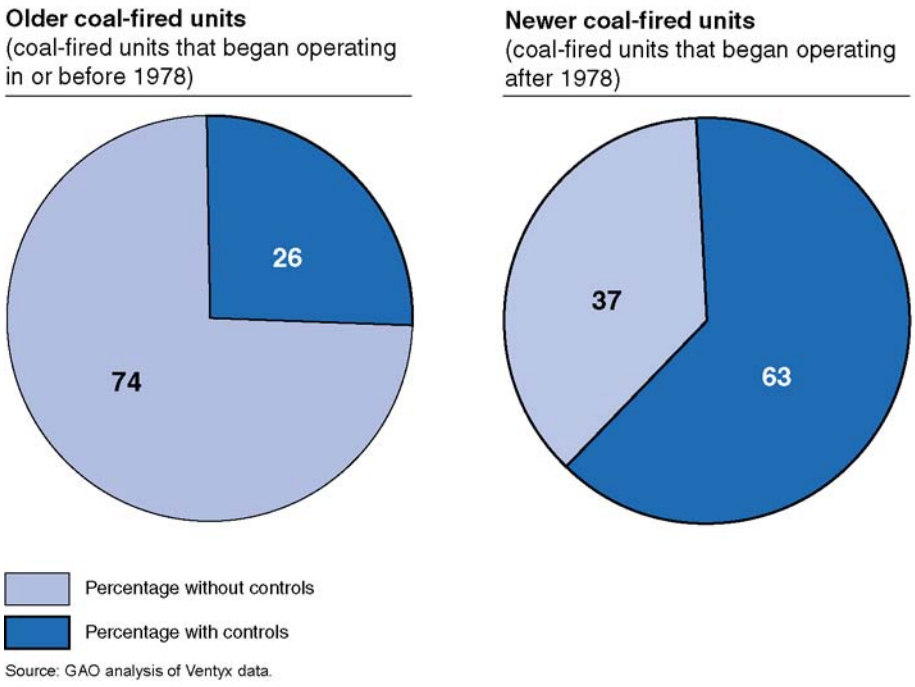
Older Units Are Less Likely to Use Emissions Controls

Another likely reason that older units have higher aggregate emissions is that many older units have not installed emissions controls. Over the last several decades, the electricity generating industry has employed a number of technologies to comply with NSR and other state and federal air quality regulations. Some of the most common and effective technologies include flue gas desulfurization unit systems, or "scrubbers," to control sulfur dioxide and SCRs to control nitrogen oxides.

Regarding the use of controls for sulfur dioxide in 2010, 63 percent of newer coal-fired units—those that began operating after 1978—had installed controls (see fig. 10). In contrast, 26 percent of older, coal-fired units had installed sulfur dioxide controls.[20]

[20]We limited this analysis to coal-fired units because these units are responsible for nearly all (99 percent) of sulfur dioxide emissions from fossil fuel units.

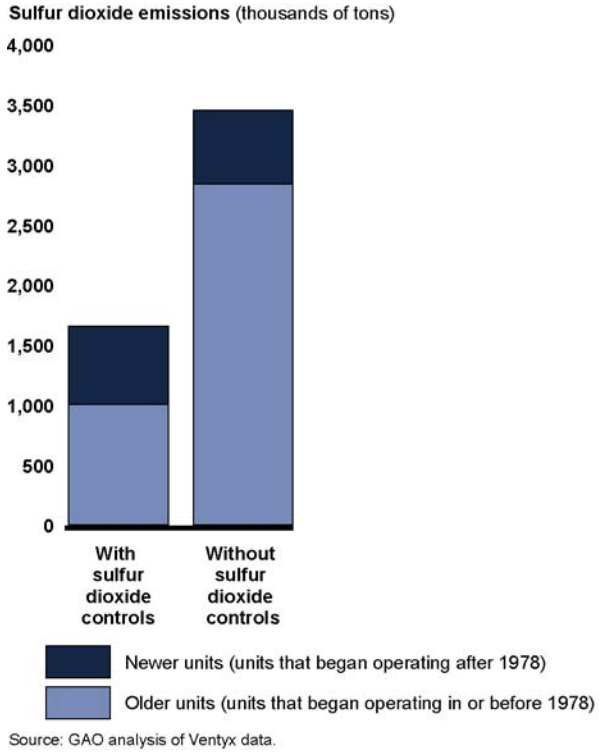
Figure 10: Use of Sulfur Dioxide Emissions Controls among Older and Newer Coal-Fired Generating Units in 2010



Source: GAO analysis of Ventyx data.

Older coal-fired units without sulfur dioxide controls were responsible for the majority of sulfur dioxide emissions from fossil fuel units in 2010. Specifically, older coal-fired units without sulfur dioxide control equipment generated about 18 percent of electricity while producing 55 percent of sulfur dioxide emissions. As shown in figure 11, older coal-fired units without sulfur dioxide controls accounted for 2.8 million tons of sulfur dioxide emissions, nearly three times as much as older units with sulfur dioxide controls. Among those coal-fired units without sulfur dioxide controls, the majority (88 percent) were older units.

Figure 11: Sulfur Dioxide Emissions from Controlled and Uncontrolled Coal-Fired Generating Units in 2010



Source: GAO analysis of Ventyx data.

The use of controls for nitrogen oxides is more widespread than for sulfur dioxide, although the effectiveness of these controls at removing nitrogen oxides varies widely. For purposes of our analysis, we classified controls for nitrogen oxides into three categories, as shown in table 2. Overall, older units were less likely than newer units to use controls for nitrogen oxides. Among older units, 38 percent had no controls for nitrogen oxides, compared with 6 percent of newer units. Older units were also less likely to have installed SCR controls, the most effective category of control for nitrogen oxides: about 14 percent of older units had such controls, compared with 33 percent of newer units.

Table 2: Controls for Nitrogen Oxides in Fossil Fuel Electricity Generating Units: Removal Efficiency and Extent of Use in 2010

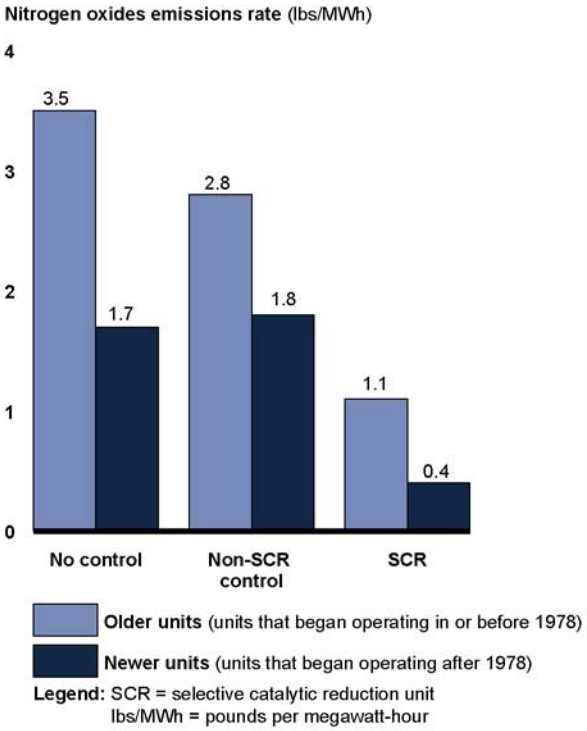
Category	Control type	Number of older units	Number of newer units
1	None	564	116
2	Selective noncatalytic reduction, low nitrogen-oxides burners, and others	708	1,204
3	Selective catalytic reduction (SCR)	213	638

Source: GAO analysis of Ventyx data.

Note: Units in categories 2 and 3 may have installed multiple nitrogen oxides controls; no units in category 2, however, had installed an SCR.

As shown in figure 12, older units collectively emitted nitrogen oxides at higher rates than newer units. For example, older units without any nitrogen oxides controls emitted an average of 3.5 pounds of nitrogen oxides per megawatt-hour of electricity generated in 2010, approximately twice the rate as newer units.

Figure 12: Emissions Rates of Nitrogen Oxides for Older and Newer Fossil Fuel Generating Units in 2010, by Type of Control for Nitrogen Oxides



Source: GAO analysis of Ventyx data.

Note: "Non-SCR" refers to any other emissions control other than an SCR (see category 2 in table 2). Chart reflects generating units that use coal, natural gas, and oil. Older generating units are mostly coal fired, whereas newer generating units rely more heavily on natural gas.

The increased use of emissions controls over time may be attributable, in part, to the Clean Air Act requirements such as NSR and the Acid Rain Program. The Acid Rain Program, created by the Clean Air Act Amendments of 1990, established a cap on the amount of sulfur dioxide that

may be emitted by electricity generating units nationwide. According to EPA officials, both NSR and the Acid Rain Program have contributed to more widespread use of emissions controls. In addition, EPA has recently finalized regulations that may prompt generating unit owners to (1) retrofit older units with emissions controls or (2) retire units that are not cost-effective to retrofit.[21] Conversely, some uncontrolled units may be limited in their ability to install certain types of emissions controls if these controls are not required.[22]

Older Units Are Generally Less Efficient Than Newer Units

The average efficiency with which electricity generating units produce electricity has improved over time, which has likely contributed to lower collective emissions among newer units. Generating efficiency is often measured by the total heat (fuel) required to generate each unit of electricity, known as a "heat rate."[23] More efficient units require less fuel to produce the same amount of electricity, generally resulting in lower emissions and fuel costs. A number of factors can affect a unit's efficiency, including its design, its operation, the choice of fuel, the use of emission controls, and the environmental conditions in which the unit operates. For example, some types of coal are more efficient than others because they have lower ash and water content. Emissions controls can also reduce a unit's efficiency because some electricity must be used to operate the controls.

As shown in figure 13, the operating efficiency of generating units built before 1950 is much lower than newer generating units. On average, in 2010, units that began operating in 2000 or later were approximately 46 percent more efficient than units that began operating before 1950. In addition to a greater reliance on coal, many older units only operate periodically, during times of peak electricity demand, which decreases their efficiency relative to units that operate on a more continuous basis.[24] While some energy efficiency technologies are available for application to existing units, the biggest efficiency gains result from the substitution of old units with new, more efficient units. Some natural gas units constructed in the last two decades, for example, are capable of achieving heat rates below 7,000 million British thermal units (Btu) per kilowatt-hour, which is substantially lower than the averages highlighted in figure 13.

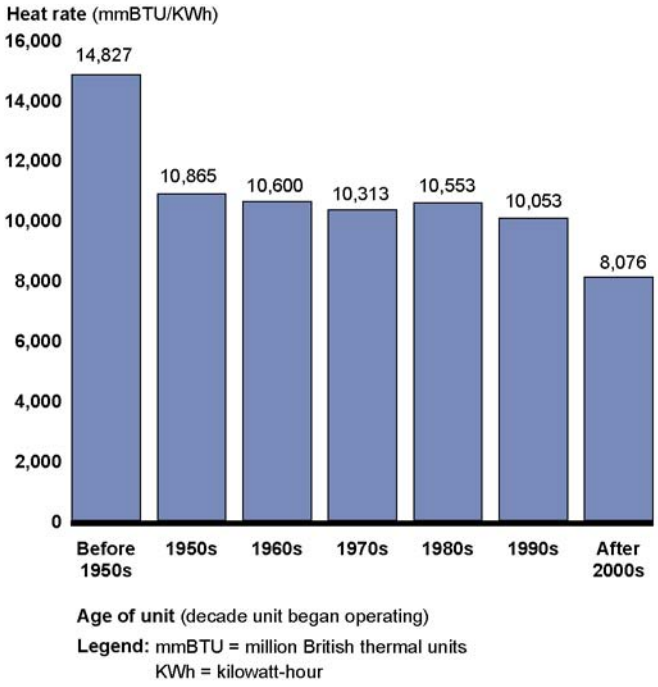
[21]These regulations include the Cross-State Air Pollution Rule—which limits sulfur dioxide and nitrogen oxides emissions from a number of states that contribute significantly to nonattainment of or interference with maintenance of certain national ambient air quality standards in downwind states—and National Emissions Standards for Hazardous Air Pollutants from Coal- and Oil-Fired Electric Utility Steam Generating Units, also known as the Mercury and Air Toxics Standards, which establish emissions limitations on mercury and other pollutants. Both regulations are being challenged in court.

[22]In many states, public utility commissions are responsible for approving the rates (or prices) electric utilities charge their customers and ensuring they are reasonable. As part of approving rates, these commissions approve such utility investments as emissions controls and, as a result, may consider whether specific technologies are reasonable. These commissions generally require some demonstration that the investment is prudent.

[23]Heat rate is a measurement used in the energy industry to calculate how efficiently an electricity generator uses heat energy. It is expressed as the number of British thermal units (Btu) of heat required to produce a kilowatt hour of energy. A lower heat rate signifies greater efficiency.

[24]Generating units that undergo frequent startups use comparatively large amounts of fuel and may be less efficient than units that operate continuously.

Figure 13: Average Efficiency (Heat Rate) of Fossil Fuel Units in 2010, by Decade Unit Began Operating



Source: GAO analysis of Ventyx data.

Note: A British thermal unit (Btu) is a standard unit of measurement used to denote the amount of heat energy in fuels. A lower heat rate indicates a higher level of efficiency. Chart reflects generating units that use coal, natural gas, and oil. Older generating units are mostly coal fired, whereas newer generating units rely more heavily on natural gas.

Nonetheless, older units remain an important part of the U.S. electricity generating sector. In 2010, older units were responsible for 45 percent of total electricity production from fossil fuel units. In certain regions, older units played a more significant role in providing electricity. For example, in the Mid-Atlantic and Great Lakes regions, older units generated 64 percent and 70 percent, respectively, of electricity coming from fossil fuel units.[25] Some older units also provide services that help ensure the reliable flow of electricity to certain regions; for example, some older units may be used to help restart the electricity system in the event of a blackout.

[25]These regions correspond to Environmental Protection Agency (EPA) Region 3 (Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, and West Virginia) and Region 5 (Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin).

Agency Comments

We provided a draft of this report to EPA and the Department of Energy for their review and comment. EPA and the Department of Energy provided technical comments, which we have incorporated as appropriate.

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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, the Administrator of EPA, the Secretary of Energy, and other interested parties. In addition, the report will be available at no charge on the GAO website at http://www.gao.gov.

If you or your staff have any questions about this report, please contact David Trimble at (202) 512-3841 or trimbled@gao.gov or Frank Rusco at (202) 512-3841 or ruscof@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 key contributions to this report were Michael Hix (Assistant Director), Ellen W. Chu, Philip Farah, Cindy Gilbert, Mitchell Karpman, Jessica Lemke, Jon Ludwigson, Nancy Meyer, Mick Ray, and Jeanette Soares.

Sincerely yours,

David C. Trimble
Director, Natural Resources and Environment

Frank Rusco
Director, Natural Resources and Environment

Enclosures - 4

Electricity-generation and Aggregate Emissions from Fossil Fuel Electricity Generating Units in 2010, By State

Table 3 presents, by state, data on fossil fuel units' electricity generation and aggregate emissions of sulfur dioxide, nitrogen oxides, and carbon dioxide in 2010.

Table 3: Electricity and Emissions from Fossil Fuel Electricity Generating Units in 2010, by State

State	Number of units	Electricity generation (megawatt-hours)	Carbon dioxide emissions (tons)	Nitrogen oxide emissions (tons)	Sulfur dioxide emissions (tons)
Alabama	88	100,961,300	84,828,993	63,336	204,195
Arizona	63	74,817,174	60,732,544	60,524	36,445
Arkansas	30	40,295,345	36,271,855	37,783	67,084
California	179	80,854,400	36,929,068	4,467	226
Colorado	58	45,728,202	44,826,939	54,088	45,391
Connecticut	39	12,497,043	8,526,856	2,783	1,955
Delaware	15	5,489,585	4,318,918	4,330	14,496
District of Columbia	2	207,916	220,765	373	874
Florida	246	188,566,114	135,313,627	79,759	144,829
Georgia	141	95,973,778	87,569,772	60,580	218,906
Idaho	7	1,566,178	693,069	113	3
Illinois	196	97,862,368	107,058,198	77,063	220,077
Indiana	126	120,785,560	124,321,920	121,844	414,638
Iowa	48	41,249,495	45,296,689	44,796	104,389
Kansas	48	35,758,838	39,757,268	48,938	45,251
Kentucky	96	96,980,846	101,053,094	93,040	270,045
Louisiana	70	70,221,777	52,344,198	47,153	102,263
Maine	11	7,902,550	3,953,551	719	821
Maryland	46	26,381,736	27,999,389	19,434	29,946
Massachusetts	48	31,174,655	19,787,576	8,181	36,892
Michigan	96	76,833,143	74,272,141	79,566	242,409
Minnesota	45	31,496,681	32,900,506	29,911	41,076
Mississippi	57	40,802,413	30,624,811	29,773	54,696
Missouri	102	77,566,300	83,182,289	58,288	235,368
Montana	12	18,752,877	21,356,366	21,728	19,896
Nebraska	29	23,688,902	26,402,103	37,402	64,184
Nevada	37	28,136,479	17,222,084	10,812	7,889
New Hampshire	7	8,069,450	5,899,639	4,612	36,833
New Jersey	107	30,081,377	19,995,676	9,937	15,270
New Mexico	35	34,294,657	32,657,348	60,256	16,570
New York	165	63,663,802	41,687,271	28,311	47,488

State	Number of units	Electricity generation (megawatt-hours)	Carbon dioxide emissions (tons)	Nitrogen oxide emissions (tons)	Sulfur dioxide emissions (tons)
North Carolina	104	78,576,396	76,242,017	53,390	120,254
North Dakota	11	28,269,255	33,609,781	54,744	124,096
Ohio	135	126,505,558	125,054,961	104,871	572,110
Oklahoma	66	60,394,162	49,876,813	71,434	85,135
Oregon	8	19,280,743	10,875,349	9,729	15,696
Pennsylvania	123	143,267,035	125,643,066	134,169	411,216
Rhode Island	8	7,094,295	3,504,392	578	18
South Carolina	71	48,054,008	44,815,737	28,123	94,641
South Dakota	8	3,255,521	3,765,854	12,433	12,589
Tennessee	85	45,166,515	46,449,221	31,239	118,723
Texas	284	318,045,099	255,708,493	145,798	461,754
Utah	26	39,211,138	37,005,962	61,415	21,598
Virginia	97	42,773,143	35,584,177	38,300	93,385
Washington	13	17,402,607	14,560,232	11,980	2,651
Wisconsin	84	46,382,410	49,753,419	33,082	109,158
West Virginia	50	79,543,178	79,135,925	53,757	109,028
Wyoming	21	42,829,664	49,382,465	60,902	64,849
Total	**3,443**	**2,754,711,668**	**2,448,972,387**	**2,105,844**	**5,157,306**

Source: GAO presentation of Ventyx data.

Note: As with most of the other data presented in this report, we limited our analysis to those units that (1) list a fossil fuel as a primary fuel, (2) have a net summer capacity greater than 25 megawatts, and (3) produced power in 2010. No reported electricity production or emissions were reported from fossil fuel units in Alaska, Hawaii, or Vermont.

Electricity Generation and Emissions Rates from Fossil Fuel Electricity Generating Units in 2010, by State

Table 4 presents, by state, data on fossil fuel units' electricity generation and emissions rates in 2010.

Table 4: Electricity Generation and Emissions Rates from Fossil Fuel Electricity Generating Units in 2010, by State

State	Number of units	Electricity generation (MWh)	Carbon dioxide emissions rate (tons/MWh)	Nitrogen oxides emissions rate (lbs/MWh)	Sulfur dioxide emissions rate (lbs/MWh)
Alabama	88	100,961,300	0.84	1.25	4.05
Arizona	63	74,817,174	0.81	1.62	0.97
Arkansas	30	40,295,345	0.90	1.88	3.33
California	179	80,854,400	0.46	0.11	0.01
Colorado	58	45,728,202	0.98	2.37	1.99
Connecticut	39	12,497,043	0.68	0.45	0.31
Delaware	15	5,489,585	0.79	1.58	5.28
District of Columbia	2	207,916	1.06	3.59	8.41
Florida	246	188,566,114	0.72	0.85	1.54
Georgia	141	95,973,778	0.91	1.26	4.56
Idaho	7	1,566,178	0.44	0.14	0.00
Illinois	196	97,862,368	1.09	1.57	4.50
Indiana	126	120,785,560	1.03	2.02	6.87
Iowa	48	41,249,495	1.10	2.17	5.06
Kansas	48	35,758,838	1.11	2.74	2.53
Kentucky	96	96,980,846	1.04	1.92	5.57
Louisiana	70	70,221,777	0.75	1.34	2.91
Maine	11	7,902,550	0.50	0.18	0.21
Maryland	46	26,381,736	1.06	1.47	2.27
Massachusetts	48	31,174,655	0.63	0.52	2.37
Michigan	96	76,833,143	0.97	2.07	6.31
Minnesota	45	31,496,681	1.04	1.90	2.61
Mississippi	57	40,802,413	0.75	1.46	2.68
Missouri	102	77,566,300	1.07	1.50	6.07
Montana	12	18,752,877	1.14	2.32	2.12
Nebraska	29	23,688,902	1.11	3.16	5.42
Nevada	37	28,136,479	0.61	0.77	0.56
New Hampshire	7	8,069,450	0.73	1.14	9.13
New Jersey	107	30,081,377	0.66	0.66	1.02
New Mexico	35	34,294,657	0.95	3.51	0.97
New York	165	63,663,802	0.65	0.89	1.49

State	Number of units	Electricity generation (MWh)	Carbon dioxide emissions rate (tons/MWh)	Nitrogen oxides emissions rate (lbs/MWh)	Sulfur dioxide emissions rate (lbs/MWh)
North Carolina	104	78,576,396	0.97	1.36	3.06
North Dakota	11	28,269,255	1.19	3.87	8.78
Ohio	135	126,505,558	0.99	1.66	9.04
Oklahoma	66	60,394,162	0.83	2.37	2.82
Oregon	8	19,280,743	0.56	1.01	1.63
Pennsylvania	123	143,267,035	0.88	1.87	5.74
Rhode Island	8	7,094,295	0.49	0.16	0.01
South Carolina	71	48,054,008	0.93	1.17	3.94
South Dakota	8	3,255,521	1.16	7.64	7.73
Tennessee	85	45,166,515	1.03	1.38	5.26
Texas	284	318,045,099	0.80	0.92	2.90
Utah	26	39,211,138	0.94	3.13	1.10
Virginia	97	42,773,143	0.83	1.79	4.37
Washington	13	17,402,607	0.84	1.38	0.30
West Virginia	50	79,543,178	0.99	1.35	2.74
Wisconsin	84	46,382,410	1.07	1.43	4.71
Wyoming	21	42,829,664	1.15	2.84	3.03
Total	**3,443**	**2,754,711,668**	-	**-**	**-**

Source: GAO presentation of Ventyx data.

Legend

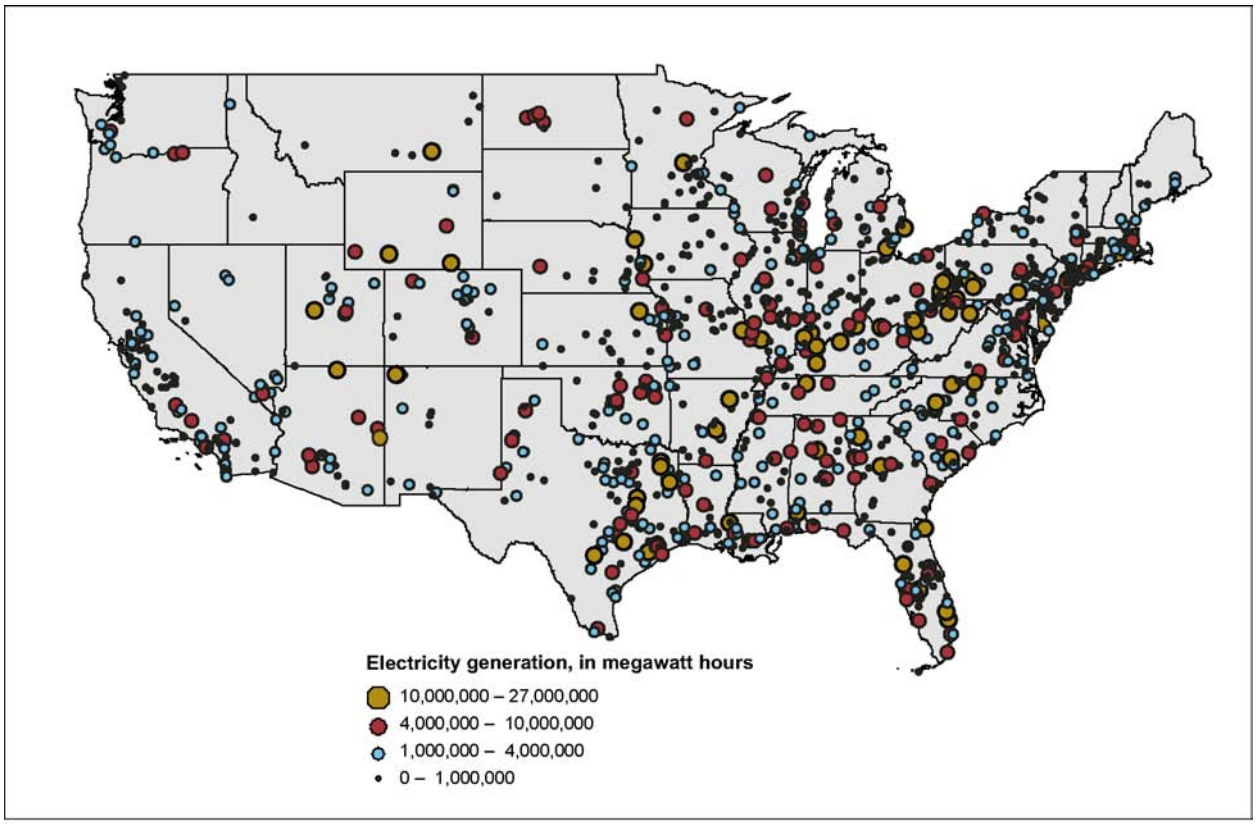
Lb = pound
MWh = megawatt-hour

Note: As with most of the other data presented in this report, we limited our analysis to those units that (1) list a fossil fuel as a primary fuel, (2) have a net summer capacity greater than 25 megawatts, and (3) produced power in 2010. No reported electricity production or emissions were reported from fossil fuel units in Alaska, Hawaii, or Vermont.

Energy and Emissions from U.S. Fossil Fuel Electricity Generating Units, by Location in 2010

Figures 14,15, 16, and 17 show the location of electricity generating units and the amount of electricity, sulfur dioxide, nitrogen oxides, and carbon dioxide they produced in 2010. Units in the Great Lakes, South Central, and Southeast regions produced most of the emissions.[26] Specifically, in 2010, units in these regions accounted for 69 percent of the sulfur dioxide, 59 percent of nitrogen oxides, and 63 percent of the carbon dioxide emitted from older units nationwide in 2010 and generated 62 percent of the elecricity from fossil fuel units.

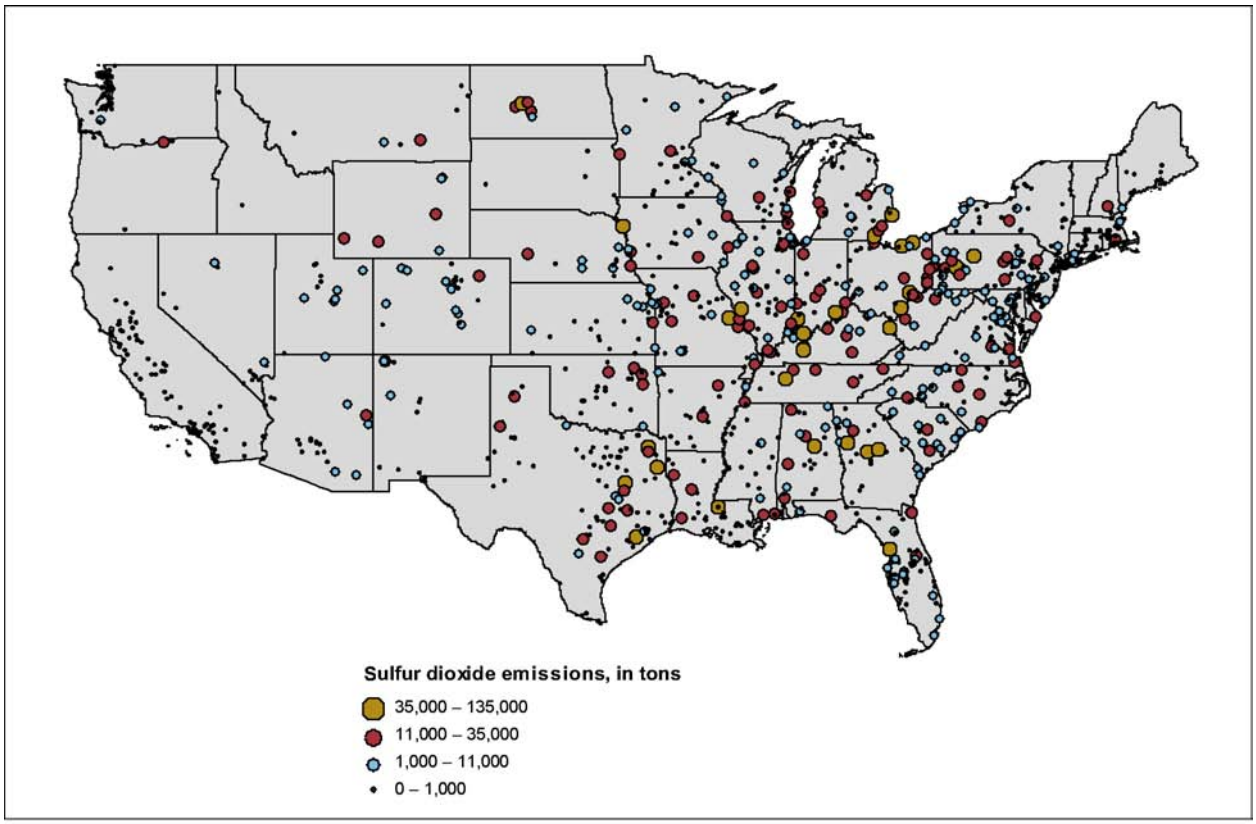
Figure 14: Geographic Distribution of Electricity Generation from Fossil Fuel Electricity Generating Units, 2010



Source: GAO analysis of Ventyx data.

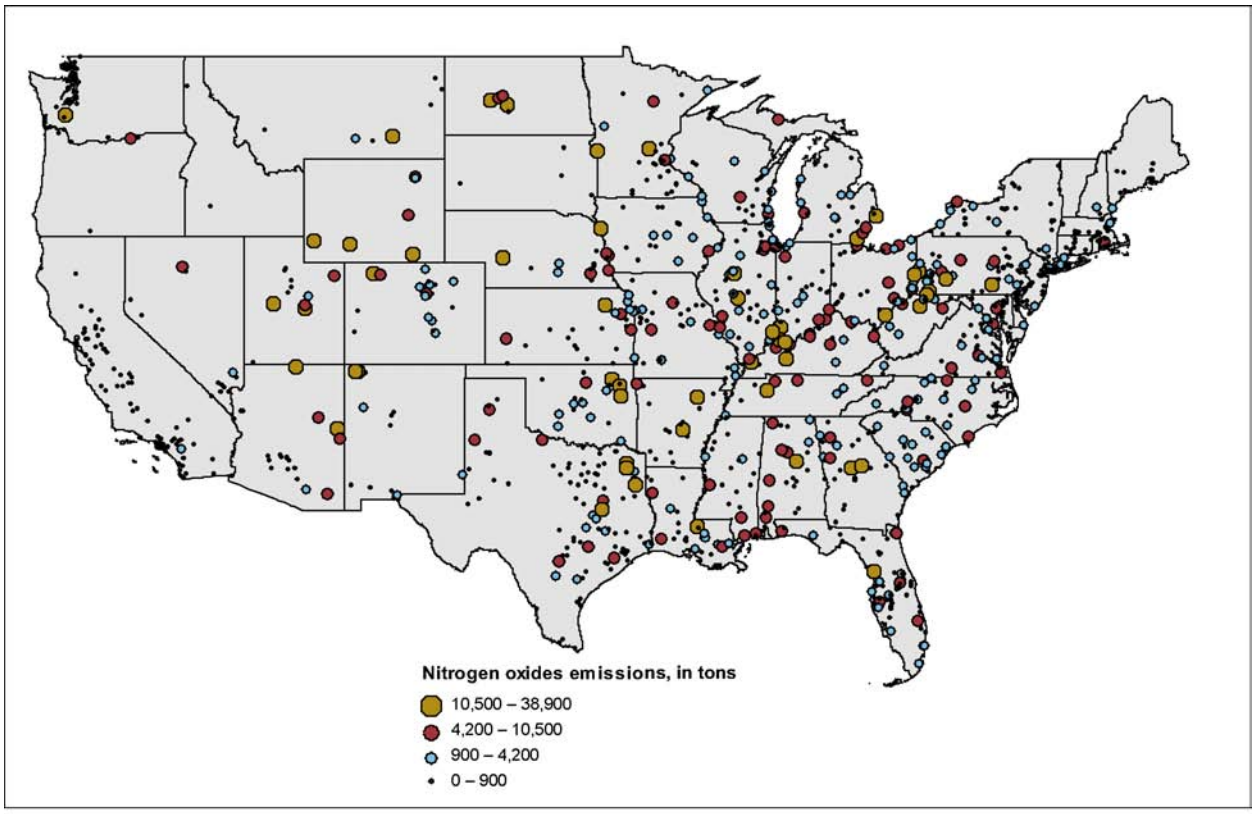
[26]These regions correspond to Environmental Protection Agency (EPA) Region 5 (Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin); Region 6 (Arkansas, Louisiana, New Mexico, Oklahoma, and Texas); and Region 4 (Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee).

Figure 15: Geographic Distribution of Sulfur Dioxide Emissions from Fossil Fuel Electricity Generating Units, 2010



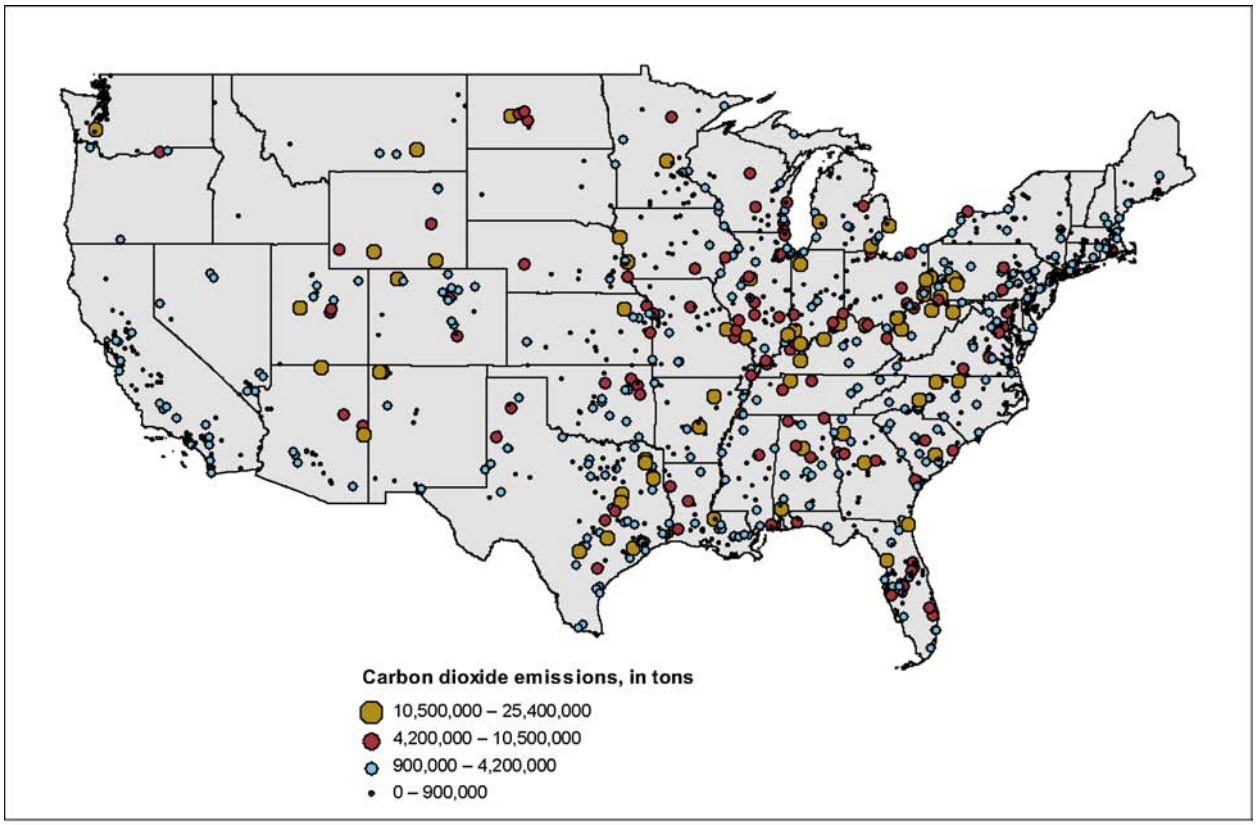
Source: GAO analysis of Ventyx data.

Figure 16: Geographic Distribution of Nitrogen Oxides Emissions from Fossil Fuel Electricity Generating Units, 2010



Source: GAO analysis of Ventyx data.

Figure 17: Geographic Distribution of Carbon Dioxide Emissions from Fossil Fuel Electricity Generating Units, 2010



Source: GAO analysis of Ventyx data.

Energy and Emissions from U.S. Fossil Fuel Electricity Generating Units in 2010, by Decade Unit Began Operating

Table 5 presents data on fossil fuel units' electricity generation, aggregate emissions, capacity, and emissions per unit of electricity generated, based on the decade the unit began operating.

Table 5: Electricity Generation and Emissions in 2010, by Decade Unit Began Operating

	Decade unit began operating					
	1950s	**1960s**	**1970s**	**1980s**	**1990s**	**2000s**
Number of units	415	382	683	232	404	1,249
Electricity generation (MWh, in thousands)	195,561	353,497	770,451	513,904	163,507	728,165
Net summer capacity (MW)	52,130	93,570	177,014	83,160	52,967	241,798
Carbon dioxide emissions (tons, in thousands)	212,070	370,819	799,849	551,016	118,900	369,887
Carbon dioxide emissions rate (lbs/MWh)	2,169	2,098	2,076	2,144	1,454	1,016
Nitrogen oxides emissions (lbs)	273,290	446,312	697,687	524,769	85,282	65,186
Nitrogen oxides emissions rate (lbs/MWh)	2.79	2.53	1.81	2.04	1.04	0.18
Sulfur dioxide emissions (lbs)	1,135,001	1,372,766	1,506,432	987,113	74,822	31,368
Sulfur dioxide emissions (lbs/MWh)	11.61	7.77	3.91	3.84	0.92	0.09

Source: GAO analysis of Ventyx data.

Legend

lb = pound
MWh = megawatt-hour

(361383)