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United States Government Accountability Office
Washington, DC 20548

May 1, 2008

The Honorable Mary L. Landrieu
Chair
The Honorable Lamar Alexander
Ranking Member
Subcommittee on Legislative Branch
Committee on Appropriations
United States Senate

The Honorable Debbie Wasserman Schultz
Chair
The Honorable Tom Latham
Ranking Member
Subcommittee on Legislative Branch
Committee on Appropriations
House of Representatives

Subject: *Economic and Other Implications of Switching from Coal to Natural Gas at the Capitol Power Plant and at Electricity-Generating Units Nationwide*

Elevated concentrations of greenhouse gases—carbon dioxide, methane, nitrous oxide, and several synthetic chemicals—in the atmosphere resulting from the combustion of fossil fuels and other sources have the potential to cause significant changes in the earth's climate. These potential impacts include shifts in sea level and weather patterns and could pose threats to coastal and other infrastructure. Concerns about the potential impacts of climate change have led the Congress to consider legislation that would place binding, nationwide limits on greenhouse gas emissions, and the House of Representatives' leadership has initiated efforts to decrease emissions attributable to its operations. Nearly all of the greenhouse gas emissions from House operations consist of carbon dioxide and are associated with electricity purchased from utilities and the combustion of fossil fuels in the Capitol Power Plant (CPP), which provides steam and chilled water for heating and cooling the Capitol building and 23 surrounding facilities. The Architect of the Capitol (AOC) operates CPP.

In June 2007, the Chief Administrative Officer (CAO) of the House of Representatives released the Green the Capitol initiative (the initiative) at the direction of the Speaker

and the Majority Leader.¹ Among other goals, the initiative calls for the House of Representatives to operate in a carbon-neutral manner by the end of the 110th Congress (December 2008). Carbon-neutral, as defined in the initiative, means that operations produce no net contribution to greenhouse gas emissions. The initiative outlines several strategies to achieve the goal of carbon neutrality, including operating CPP with natural gas instead of coal to meet the needs of the House. (Natural gas generates about half as much carbon dioxide as coal when burned but costs about four times more for a comparable amount of energy input.)² Based on an AOC estimate, the House's share of the cost of achieving the fuel-switching goal would total \$2.75 million in fiscal year 2008. The Omnibus Appropriations Act for that year appropriated \$85.3 million for CPP. The House Appropriations Committee Explanatory Statement directs \$3.27 million of this amount to the Green the Capitol initiative.³

CPP produces steam using a combination of seven boilers—two boilers that primarily burn coal, but could also burn natural gas, and five boilers that burn fuel oil or natural gas. These boilers burn fuel to convert water to steam that, in turn, provides energy primarily for space heating but they do not generate electricity.⁴ The total capacity of these boilers is over 40 percent higher than the maximum capacity required at any given time, and the plant has the flexibility to switch among the three different fuels or burn a combination of fuels. The percentage of energy input from each fuel has varied from year to year, with an average fuel mix of 43 percent natural gas, 47 percent coal, and 10 percent fuel oil between 2001 and 2007. The overall amount of steam required depends on numerous factors, including weather, the adoption of voluntary and federally mandated energy-efficiency and conservation measures, and the addition of new buildings (such as the Capitol Visitor Center, scheduled to open in late 2008).

¹Chief Administrative Officer of the House of Representatives, *Final Report, Green the Capitol Initiative* (June 21, 2007). The Green the Capitol initiative establishes the goal of carbon neutrality for the House of Representatives only, whereas CPP also serves the Senate and additional congressional buildings.

²According to the Department of Energy's Energy Information Administration, the amount of carbon dioxide emitted from burning pipeline natural gas is 117.08 pounds per million British thermal units (Btu) of energy. The amount generated from burning coal ranges from 205.3 pounds to 227.4 pounds per million Btu and depends on the specific type of coal burned.

³Consolidated Appropriations Act, 2008, Committee Print of the House Committee on Appropriations on H.R. 2764 / Public Law 110-161 (Legislative Text and Explanatory Statement), 153 Cong. Rec. H15479, H15741 (Dec. 17, 2007). According to a House Appropriations Committee summary of the initial House-passed legislative branch appropriations bill, the Green the Capitol initiative funding in the earlier bill included "...\$2.7 million to shift from coal to cleaner burning natural gas for heating needs, \$520,000 to switch to 100 percent renewable wind power for electrical needs, \$500,000 for an ethanol gas station for House automobiles, and \$100,000 for energy efficient compact florescent light bulbs." (See http://appropriations.house.gov/press_releases_2007.aspx, follow link under "August.")

⁴In addition to space heating, these boilers provide energy for other minor services, including humidification and food services. The House of Representatives purchases electricity from an external provider.

In addition to the House's efforts to implement the Green the Capitol initiative, the Congress is considering proposals that would create nationwide limits on greenhouse gas emissions from electricity-generating units and other sectors of the economy. Many of these proposals would involve the use of mechanisms that create an economic incentive for emitters to decrease their emissions by limiting the overall allowable quantity of emissions or by placing a direct price on each unit of emissions. Because the combustion of fossil fuels results in greenhouse gas emissions, efforts to limit emissions could lead to overall shifts in the prices and demand for different types of fuels. For example, the Department of Energy has projected that limits on greenhouse gases would shift the nation's demand for fossil fuels by decreasing the demand for coal and increasing the demand for natural gas. In 2006, production of electricity from coal totaled 49 percent of the nation's net generation, followed by 20 percent from natural gas, 19 percent from nuclear power, and 7 percent from hydroelectric power, with lesser quantities produced from other renewable sources, petroleum, and other fuels. These percentages have remained relatively stable in recent years with a slight increase in natural gas generation and a slight decrease in generation from coal. In principle, all coal units could be physically switched from coal to natural gas with varying degrees of modification. It would also be possible to build new gas-fired power plants to replace coal-fired power plants. These modifications or replacements would require different amounts of investment in the power plants themselves, as well as related infrastructure. Legislative proposals that would impose limits on greenhouse gas emissions from the electricity sector raise important questions about the potential supply and demand for different fuels under different scenarios, as well as about the ability of existing generating units to switch from burning high-emitting fuels, such as coal, to lower-emitting fuels, such as natural gas. Moreover, such proposals prompt questions about the overall economic benefits and costs that would accrue.

Within this context, the House Committee on Appropriations directed us to determine, in consultation with the Department of Energy, (1) the expected increase in natural gas use for House operations and the associated costs at CPP that would result from the Green the Capitol initiative, and (2) the ability of existing U.S. coal-burning, electricity-generating units to switch to burning natural gas and the associated economic implications.

To respond to the first objective, we first reviewed two studies prepared for the House CAO. One study was an analysis prepared by AOC that served as the basis for the fuel-switching funding estimate in the Green the Capitol initiative presented by CAO to the House leadership. The other study was a subsequent analysis prepared by the Department of Energy's Lawrence Berkeley National Laboratory (LBNL). We then determined the average annual quantity of each fuel (measured in British thermal units or Btu) consumed by the plant between 2001 and 2007. Next, we calculated the proportion of the plant's steam output consumed by buildings operated by the House of Representatives, which we estimated was 29 percent based on the total square footage of buildings served by the plant. We assumed that the fuel-switching approach outlined in the initiative required that this proportion of the plant's output be derived entirely from natural gas. The remaining 71 percent would

continue to reflect the plant's historical average of 43 percent natural gas, 47 percent coal, and 10 percent fuel oil. We did not assume a change in the quantity of fuel oil that would be burned by the plant because of technical considerations at the plant that require the use of fuel oil as a back-up fuel. We then calculated the incremental cost of achieving an adjusted fuel mix. We made this calculation assuming that, beginning in 2008, the demand for the plant's output would decrease by 1 percent annually from the 2001 through 2007 baseline due to energy efficiency legislation and additions to the Capitol complex. We then estimated future CPP cost per unit of fuel for the period from 2008 through 2012 using historical data on AOC's fuel expenditures and projections of fuel prices for the industrial sector from the Annual Energy Outlook of the Energy Information Administration (EIA) within the Department of Energy. We adjusted EIA's projected fuel prices to account for historical differences in the average prices paid by industrial users of these fuels and the prices paid by AOC. All of our cost estimates are in constant 2006 dollars. In preparing our estimates, we consulted with AOC staff, officials representing the House CAO, and the Department of Energy (including LBNL and EIA). We also reviewed relevant studies prepared by these agencies.

To respond to the second objective, we analyzed available data from the Department of Energy and other sources. We also obtained information from key stakeholders identified in discussions with the department that represent the electricity generation, natural gas, and coal industries using written interview questions. Enclosure I provides a more detailed description of our scope and methodology. We conducted our audit work between October 2007 and April 2008 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.

Summary

According to our analysis, implementing the Green the Capitol initiative's fuel-switching directive to decrease carbon dioxide emissions from the CPP should lead to a 38 percent increase in natural gas use over the average annual quantity consumed between 2001 and 2007. We estimated that the fuel switching should cost about \$1.4 million in fiscal year 2008 and could range from between \$1.0 and \$1.8 million depending on actual fuel costs, among other factors. Our cost estimates are less than the \$2.75 million AOC budgeted for this purpose in fiscal year 2008, largely because we employed a different methodology than AOC when it prepared its estimates and maintained certain assumptions that AOC did not. Specifically, AOC based its estimates on a scenario in which the plant would eliminate its use of coal altogether and burn natural gas exclusively, for a total cost of \$7.78 million. Of this total cost, AOC estimated that \$2.75 million represented the portion that could be applied to the House, based on the number of square feet of building space served by the plant. In its estimate, AOC also did not account for the fact that the Ford House Office Building obtains steam from the General Services Administration rather than

from CPP. As a result, AOC's plans to fulfill the Green the Capitol initiative involve increasing natural gas use by 48 percent, an increase that far exceeds the initiative's fuel-switching recommendation. In contrast, our analysis focused on estimating the incremental cost of adjusting the plant's fuel mix such that the portion of its output that serves buildings operated by the House (about 29 percent on a square footage basis) would consist entirely of natural gas. This equates to increasing the level of natural gas from 43 percent to 60 percent of the historical fuel mix, a net difference of 17 percentage points and a 38 percent increase in overall natural gas consumption. Importantly, the plant's existing natural gas boilers have the capacity to accommodate this increase in natural gas use and CPP would not have to eliminate its use of coal altogether. Looking ahead, we estimate that the incremental cost of maintaining the adjusted fuel mix will range between \$4.7 million and \$8.3 million over the 2008 through 2012 time period, depending on fuel prices, the plant's output, and other factors. However, an important uncertainty with our estimates stems from the fact that AOC does not have complete, reliable information on the efficiency of its seven boilers in converting fuel into steam or on the full costs associated with the use of each fuel, taking into account factors such as fuel transportation and handling, and fuel-specific pollution control devices. As a result, AOC does not have all the information it needs to make fully informed decisions about operating the plant as efficiently or cost-effectively as possible. While the increased use of natural gas and decreased use of coal will increase costs above a business-as-usual baseline scenario, the initiative would likely generate other important benefits. These benefits include decreased emissions of carbon dioxide and pollutants that cause smog and acid rain, as well as potential reductions in the plant's operating costs associated with the transportation, storage, handling, and treatment of coal and related waste streams.

With regard to the ability of U.S. coal-burning, electricity-generating units to switch to natural gas, according to available data and key stakeholders, the ability of these units to switch is limited by high natural gas prices, supply constraints, and existing infrastructure. In addition, increasing the nation's use of natural gas for electricity generation could result in adverse economic consequences. Natural gas currently costs about four times more than coal per British thermal unit and has shown a relatively higher rate of price increases and volatility over time relative to coal, according to EIA. In addition to higher fuel costs, supply constraints limit the practicality of replacing electricity generated from coal with natural gas. The United States has limited capability to meet the growing demand for natural gas with domestic production and would need to become increasingly dependent on international supplies of natural gas if there was widespread switching to natural gas from coal. Even taking imported natural gas into account, key stakeholders doubted whether natural gas supply could meet the demand if plant operators decided to pursue fuel switching. Fuel switching to natural gas also poses challenges related to existing infrastructure, including limited pipeline and storage capacity and technical and regulatory barriers to the conversion of existing coal plants. Large-scale fuel switching would require substantial investments in pipeline and storage capacity and new terminals to process imported natural gas—all of which would require regulatory approval. With respect to the conversion of existing coal-burning plants, stakeholders said that it would be more feasible and cost-effective to construct new

natural gas units or dispatch excess capacity at existing natural gas units than to convert a coal plant because of technical and economic factors, among other reasons. For example, retrofitting an existing coal unit to burn natural gas would require significant capital expenditures, while also potentially decreasing the unit's overall efficiency in converting fuel input into electricity. Because of these technical and other issues, large-scale shifting demand for electricity production from coal to natural gas would increase electricity prices, residential and commercial heating costs, and fuel costs for certain industries that consume large quantities of natural gas, including chemical and fertilizer manufacturers. Because of these and other concerns, key stakeholders said that switching coal plants to natural gas has occurred infrequently in the past and is not likely to occur in the future.

We are recommending that, before adjusting the Capitol Power Plant's fuel mix beyond the level directed by the Green the Capitol initiative, the Acting Architect of the Capitol consult with AOC's oversight committees in the Congress and evaluate the economic and environmental tradeoffs associated with the use of each fuel at the plant, taking into account the efficiency of the plant's boilers, related fuel supply systems, and pollution control equipment.

We provided a draft copy of this report to the Acting Architect of the Capitol for review and comment. AOC provided comments via electronic mail. AOC officials said that they agreed with our cost estimate under the high fuel price scenario but expressed concerns about the potential level of resources that would be required to respond to our recommendation. We subsequently met with AOC officials who said that they were concerned that implementing our recommendation would require them to collect exact information on the efficiency of its boilers and fuel supply systems. Based on this discussion, we adjusted the wording of the recommendation to clarify that this was not our intent. AOC also provided a number of technical clarifications regarding the plant's operation and their cost estimates for fuel switching, which we incorporated into our report as appropriate.

Fuel Switching at the Capitol Power Plant Is Expected to Require a 38 Percent Increase in Natural Gas Use at a Cost of about \$1.4 Million in Fiscal Year 2008

Based on available data and key assumptions about the plant's operation and future fuel costs, we estimated that fulfilling the Green the Capitol initiative's fuel-switching directive would require the plant to increase its natural gas use by 38 percent relative to its baseline level of fuel consumption between 2001 and 2007. As a portion of the plant's total fuel mix, natural gas would increase from about 43 percent of overall energy input to about 60 percent of input. Using information from the AOC on its fuel expenditures and fuel price projections from EIA, we estimate that implementing the fuel-switching directive could range in cost from \$1.0 to \$1.8 million in fiscal year 2008.

Because our calculations involve projections and assumptions about key variables, the estimates are inherently uncertain and actual expenditures may vary depending

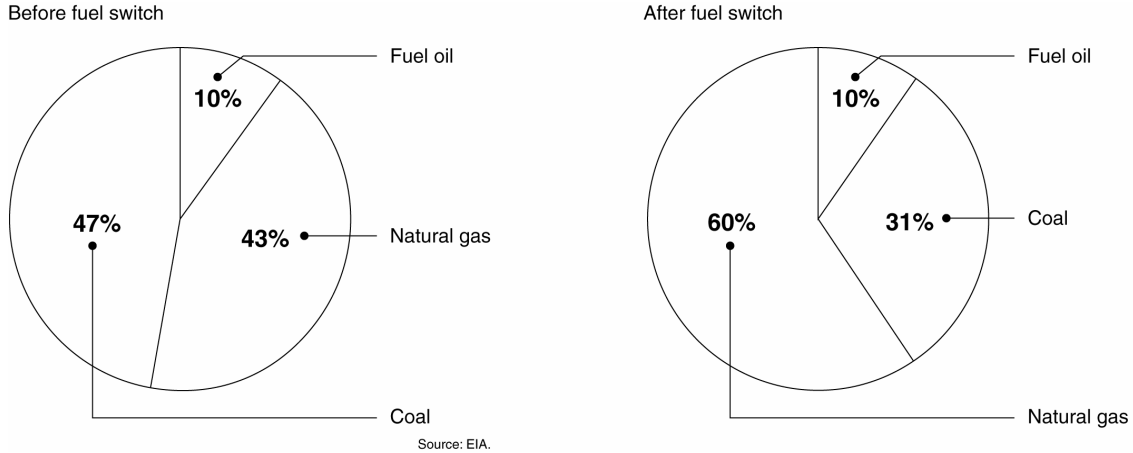
on changes to these variables. Key variables and assumptions underlying our estimates include the following:

- *Baseline fuel consumption and steam production.* We estimated the quantity of additional natural gas required to fulfill the initiative's fuel-switching goal for the year 2008. We assumed that the fuel-switching approach outlined in the initiative required that 29 percent of the plant's output be derived entirely from natural gas. The 29 percent figure is based on an estimate of the House's share of the total square footage of buildings served by the plant. The remaining 71 percent would continue to reflect the average fuel mix over the 2001 to 2007 time period.⁵ Using an average, as opposed to a single year's level of production, provides a more realistic picture of the plant's historical operation. We held the amount of fuel oil constant because of technical considerations at the plant that require using oil as a backup fuel.
- *Boiler efficiency.* We assumed that each of the seven boilers at the power plant converts fuel into steam with equal efficiency. We made this assumption based on research conducted by an independent consultant to GAO, a previous analysis conducted by Ross Associates (a consultant to AOC), and discussions with AOC staff. Overall, we found that AOC does not have complete, reliable information on the efficiency of its seven boilers in converting fuel into steam or on the full costs associated with the use of each fuel, taking into account factors such as transportation, handling, and pollution control. As a result, AOC does not have all the information it needs to make fully informed decisions about operating the plant as efficiently or cost-effectively as possible. While the available data suggests that our assumption is reasonable, the lack of complete, reliable data on efficiency of each of the boilers and related fuel supply equipment represents an important uncertainty with our analysis.
- *Fuel costs.* To estimate the cost of each fuel in fiscal year 2008, we used fuel price projections from EIA's Annual Energy Outlook 2008, which we then adjusted to account for historical differences in the prices paid by AOC versus the average price paid by industrial consumers.⁶

⁵The plant's coal boilers underwent a number of renovations and repairs, including a grate replacement, in 2005 and 2006. This may have decreased the amount of coal that the plant would have otherwise burned in those years, leading to a lower average baseline level of coal use.

⁶The difference between AOC's per unit cost of a given fuel and the corresponding average U.S. price of the same fuel in the industrial sector can be due to various factors, including transportation costs.

Figure 1: Projected Change in CPP Fuel Use



Note: Due to rounding, percentages do not add up to 100 percent in both charts.

Our Estimates Are Substantially Lower than Previous Estimates and the Level of Funding AOC Budgeted for Fuel Switching at the Plant

Our estimated costs of increasing natural gas use at CPP to meet the initiative’s fuel-switching directive fall well below a previous estimate prepared by AOC. Specifically, AOC estimated that the cost in fiscal year 2008 would total about \$2.75 million. In fiscal year 2009, AOC is requesting a much lower amount—1.22 million—to complete the fuel switch. In its own analysis, LBNL estimated the total cost for fiscal year 2008 at about \$1.88 million.

The discrepancy between our estimates and those developed by AOC and LBNL stems from variations in the methodologies each party employed. Specifically, AOC’s analysis involved a scenario in which the plant would burn only natural gas and eliminate the use of coal and fuel oil altogether. This analysis estimated that switching the entire plant to natural gas would cost a total of about \$7.8 million in fiscal year 2008. Based on this analysis, AOC then estimated that the cost of fuel switching under the initiative would equal approximately 35 percent of the total cost of switching the entire plant. The 35 percent figure was based on the assumption that the House consumed that proportion of the plant’s total output, based on the number of square feet of building space served by the plant. This yielded an estimate of \$2.75 million to switch fuels in fiscal year 2008. To fulfill the initiative’s fuel switching directive, AOC officials said that they planned to increase natural gas use from 42 percent of fuel use to 62 percent. According to our analysis, this would increase natural gas use beyond the initiative’s goals.

The analysis conducted by LBNL estimated the total cost at \$1.88 million in 2008, a substantially lower figure than the previous estimate developed by AOC. Key differences between our methodology and the methodologies employed by AOC and LBNL follow:

- We based our cost estimates on EIA fuel price projections for fiscal year 2008 and used AOC historical cost data from 2001 through 2007 to estimate the actual cost of the fuel after delivery. In contrast, AOC’s analysis used an average of their natural gas costs from 2005 through 2007, which may have inflated the cost estimates, since there were some very high natural gas price spikes during these years. LBNL used natural gas prices from fiscal year 2007.
- We assumed that House buildings use approximately 29 percent of the steam generated by the plant, based on data from AOC’s 2006 Annual Report to Congress. We excluded the Ford House Office building from our analysis because it obtains steam from General Services Administration rather than from the plant. In contrast, AOC and LBNL included the Ford Building, which resulted in estimates of 31 percent and 35 percent, respectively.

Estimated Annual Fuel-Switching Costs Are Expected to Range from \$1.2 to \$1.4 Million between 2008 and 2012

In addition to estimating the costs for fiscal year 2008, we projected the costs of maintaining the adjusted fuel mix over the 2008 through 2012 time period. Specifically, we estimated that CPP would spend roughly \$1.2 to \$1.4 million per year over the next 5 years. This amount could run as high as \$1.8 million in fiscal year 2009 or as low as \$823,000 in 2012, depending on fuel prices. Table 1 summarizes the potential future costs of maintaining an adjusted fuel mix at CPP and, because of uncertainties about fuel price projections, includes low and high fuel price scenarios.

Table 1: Projected Cost of Maintaining Adjusted Fuel Mix, 2008 through 2012

Fiscal year	Low fuel price scenario	Baseline scenario	High fuel price scenario
2008	\$1,002,632	\$1,385,488	\$1,768,343
2009	1,045,606	1,435,660	1,825,714
2010	952,500	1,316,872	1,681,244
2011	868,061	1,210,391	1,552,721
2012	823,029	1,151,236	1,479,443
Totals	\$4,691,828	\$6,499,647	\$8,307,465

Similar to our fiscal year 2008 estimate, these projections rely on a number of assumptions which, if changed, would substantially affect the overall cost. In addition to the assumptions cited above, the following factors and assumptions could affect the accuracy of our estimates:

- *Fuel demand.* We estimated that the demand for the plant’s steam would decline by 1 percent annually relative to a baseline level of demand equal to that we derived by averaging the annual demand for fiscal years 2001

through 2007. We based the 1 percent annual decline in demand on two important and partially offsetting considerations:

- Additions to the Capitol Complex, including the Capitol Visitor Center, are expected to increase the plant's steam demand by 1 percent each year through 2025.
 - The Energy Policy Act of 2005 requires a 2 percent reduction in energy use per year for federal buildings. Because over a quarter of House energy use is for heating, the act's implementation may significantly reduce steam demand over time.
- *Fuel costs.* We used fuel price projections for the U.S. industrial sector from EIA for the years 2008 through 2012 and adjusted them to reflect our estimate of the historical difference between these prices and the AOC per-unit cost of each fuel. Because of the uncertainty of fuel price projections, we constructed a low-price scenario and a high-price scenario for the years 2008 through 2012 based on measures of variability in the historical prices of these fuels.

Of these variables and assumptions, those associated with future fuel prices pose the greatest uncertainty. As we have previously reported, prices may depend on a variety of factors, such as supply, demand, available infrastructure, market conditions, and severe weather events.⁷ Since 1999, market conditions generally have fostered an upward trend in natural gas prices that, according to EIA, will continue until 2009. Starting in 2010, EIA expects natural gas prices to decline until approximately 2016.

Other important considerations can affect demand for the plant's services, including planned or future investments in energy efficiency, weather, and changes in energy or environmental legislation. Because of the uncertain and potentially offsetting effects of these factors on demand for the plant's services, we did not address them in our estimates.

Fuel Switching Would Reduce Carbon Dioxide Emissions at an Average Cost of about \$139 per Ton; Other Benefits May Also Accrue

Based on our cost projections for fiscal year 2008, we estimate that the fuel switch would yield carbon dioxide reductions of about 9,970 metric tons⁸ per year at an average cost of \$139 per ton. We developed this estimate using our \$1.4 million cost estimate as a base price and applying EIA's carbon dioxide conversion factors for coal and natural gas. (The world's largest carbon market, the European Union's Emissions Trading Scheme, currently prices a metric ton of carbon at approximately

⁷GAO, *Natural Gas: Factors Affecting Prices and Potential Impacts on Consumers*, [GAO-06-420T](#) (Washington, D.C.: Feb. 13, 2006).

⁸A metric ton is equal to 2,205 pounds, while a short ton, a measurement used in the United States is equal to 2,000 pounds.

\$37.) Additional information on the cost-effectiveness of the fuel-switching strategy relative to other carbon dioxide abatement options would help inform future decision making on fuel switching and related investments intended to decrease emissions. In April 2007, we recommended that legislative branch agencies establish a schedule for conducting energy audits and implement selected projects as part of a plan to reduce emissions.⁹ Such audits have the potential to identify projects that compare favorably to fuel switching.

In addition to reducing carbon dioxide emissions, decreasing the plant's reliance on coal may yield other environmental and health benefits. While coal currently costs less than natural gas, coal's combustion generally produces more carbon dioxide and air pollutants compared to natural gas. These pollutants, in turn, pose a variety of adverse health effects. For example, nitrogen oxides may exacerbate existing conditions such as asthma, and particulate matter has been linked to heart attacks and chronic bronchitis. Furthermore, acid rain may occur when the sulfur dioxide produced in the combustion of coal at the plant reacts with other chemicals in the atmosphere to form sulfuric acid. Burning less coal may also help Washington, D.C., and neighboring jurisdictions in their efforts to achieve compliance with federal air quality standards. Currently, the city is noncompliant for ground-level ozone and fine particulate matter. Finally, fuel switching has the potential to reduce costs associated with the transportation, storage, and handling of coal and related waste streams. In addition, coal storage, handling, and related air pollution abatement require the use of electricity, a major source of carbon dioxide, nitrogen oxide, and mercury. As a result, increasing the plant's reliance on natural gas may also yield reductions in such emissions from the power plant and the electricity generating units that provide the plant with electricity.

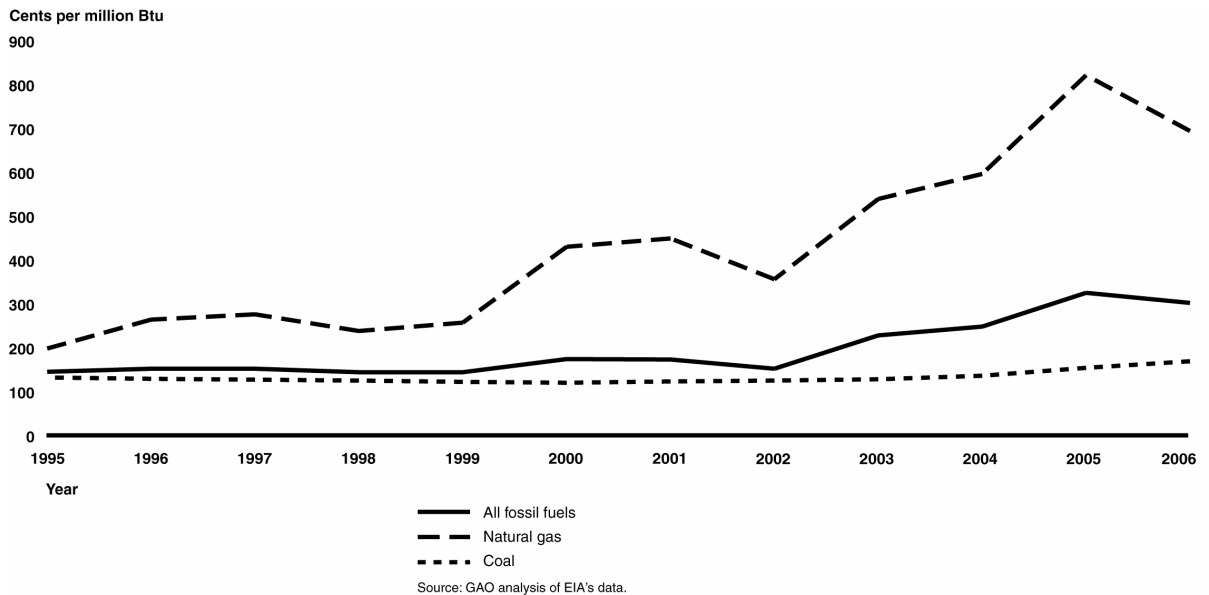
The Ability of U.S. Electricity-Generating Units to Switch from Coal to Natural Gas Is Limited, and Fuel Switching Could Cause Adverse Economic Consequences

Relatively High Natural Gas Prices Limit the Potential for Fuel Switching from Coal

According to industry stakeholders, switching from coal to natural gas for electricity generation is generally not economically feasible due to the relatively high price of natural gas compared to coal, as illustrated in figure 2.

⁹GAO, *Legislative Branch: Energy Audits Are Key to Strategy for Reducing Greenhouse Gas Emissions*, [GAO-07-516](#) (Washington, D.C.: Apr. 25, 2007).

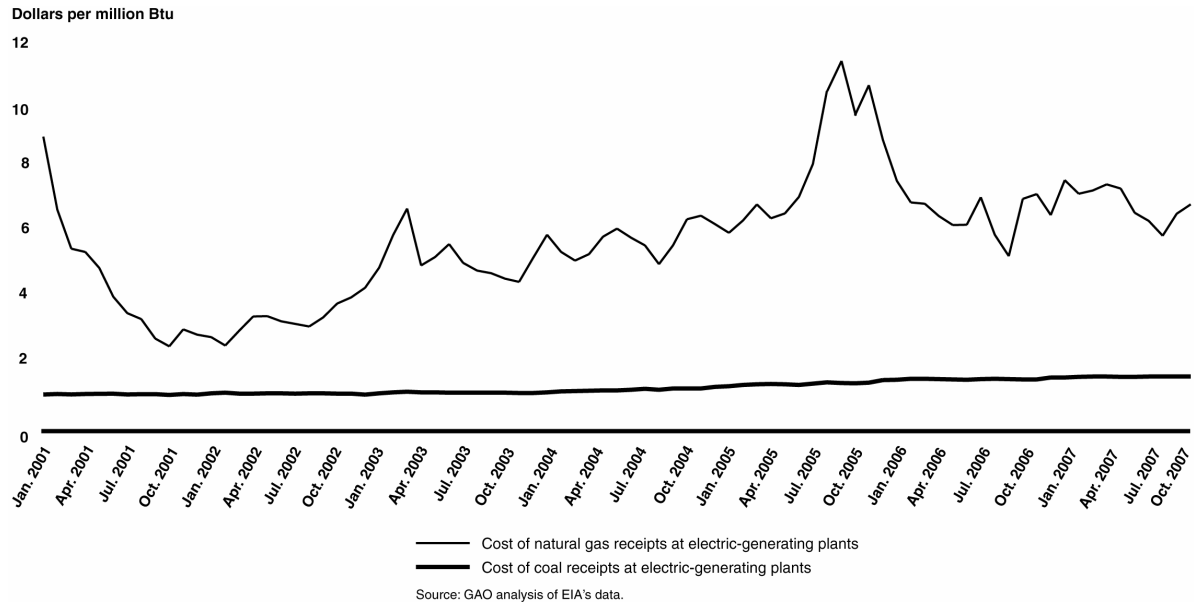
Figure 2: Average Cost of Fuels for the Electric Power Industry, 1995 through 2006



Note: Average cost is not adjusted for inflation.

Currently, natural gas costs about four times more than coal per British thermal unit. Due to its higher cost, substituting natural gas for coal would increase operating costs for electricity-generating units. Natural gas fuels about 20 percent of electricity production in the United States and, according to one stakeholder, accounts for 55 percent of the electric utility industry's entire fuel expense (\$50 billion out of \$91 billion). In addition, natural gas has shown a higher rate of price increases over time relative to coal, according to EIA, and as illustrated in figure 3, natural gas prices have been volatile in recent years. The market for natural gas has been susceptible to extreme price swings when unexpected changes occur in the market, such as weather-related spikes in demand or supply constraints caused by hurricane damage.

Figure 3: Natural Gas and Coal Costs at U.S. Electric-Generating Plants, 2001 through 2007



Constrained Natural Gas Supply Limits Fuel Switching from Coal

In addition to the relatively high price of natural gas, the ability of coal-fired, electricity-generating units to switch fuels is constrained by the available supply of natural gas. According to industry stakeholders, the United States already faces serious supply problems without a potential increase in demand due to fuel switching. According to industry stakeholders and available EIA data, U.S. natural gas production peaked in 1973, and the average productivity of natural gas wells in the United States has declined for the past 35 years due to diminishing output of older wells and lower yields and higher depletion rates from more recent discoveries. EIA projects that natural gas production will not increase in the lower 48 U.S. states over the next 20 years. According to industry stakeholders, the United States has already found and used its easily recoverable natural gas and finding new gas requires drilling deeper and in more inaccessible locations, raising production costs. One stakeholder said that it is increasingly difficult to keep output constant because about one-third of U.S. natural gas production has to be replaced every year. Thus, the United States has limited capability to meet growing demand for natural gas with domestic production.

Consequently, widespread fuel switching at electricity-generating units would increase demand for natural gas beyond the capabilities of existing and projected supply. Stakeholders noted that the United States would require nearly twice as much natural gas supply by 2030, as currently projected by EIA, if the United States were to replace all coal-fired plants with natural gas. According to one stakeholder, replacing even one-half of coal-fired generation after 2015 with natural gas would lead to an overwhelming demand. Industry stakeholders said it is not possible to

increase supplies by this magnitude, especially in light of a trend toward increased global demand and consumption.

Because of limited domestic supplies, meeting additional demand would require imports from Canada, pipelines from Alaska, or liquefied natural gas (LNG) from overseas suppliers.¹⁰ According to one stakeholder, imports, primarily from Canada, have steadily grown to comprise about 10 to 15 percent of U.S. supply. However, Canadian exports are declining as a result of decreased drilling and increased domestic demand. EIA identifies this as a significant problem facing the U.S. natural gas market, according to one stakeholder. In addition, prospects for an Alaskan pipeline and other pipelines are unclear, creating further supply concerns for the U.S. market.

With widespread fuel switching, the United States would be more dependent on imported LNG, according to industry stakeholders. The EIA's Annual Energy Outlook 2007 projected major increases in LNG imports into the United States. According to one stakeholder, all of the natural gas required by large-scale fuel switching with LNG by 2015 would require more than 50 percent of the global supply. Another stakeholder estimated that LNG supplies would be insufficient for the United States to fully switch from coal to natural gas unless the United States captured at least 90 percent of the world LNG market, which seems highly unlikely because of the significant projected growth in natural gas demand in the rest of the world.

¹⁰EIA defines LNG as natural gas (primarily methane) that has been liquefied by reducing its temperature to -260 degrees Fahrenheit at atmospheric pressure. LNG and other liquefied petroleum gases are liquefied through pressurization for convenience of transportation.

Fuel Switching for Electricity-Generating Units Would Require Investment in New and Existing Infrastructure

Switching from coal to natural gas would require investment in new infrastructure and changes to existing infrastructure, including pipeline and storage capacity and generation technologies employed at existing coal plants. In theory, all coal units can be physically switched from coal to natural gas, but stakeholders said this practice would not occur broadly due, in part, to inadequate existing distribution networks and storage capacity, including pipelines.

According to stakeholders, burning natural gas at an existing coal plant would require a pipeline with the ability to meet the plant's fuel supply requirements. If not, a new gas pipeline would have to be sited, permitted, designed, and constructed. Almost all coal-fired boilers use some natural gas to ignite and regulate combustion, but they require relatively small amounts of natural gas with correspondingly small supply pipelines. Thus, existing coal-fired units would have to enhance their supply pipelines to switch to natural gas. As a result, according to stakeholders, a major fuel-switching program would require a nationwide natural gas infrastructure construction program. This would require expansion of interstate and intrastate pipelines to transport increased volumes of natural gas. Furthermore, existing plants and local natural gas distribution systems would have to increase their storage capacity. Local storage can help buffer variations in demand, and addressing local storage requirements could pose challenges, according to stakeholders. Increased reliance on natural gas would also require other new infrastructure, such as LNG terminals.

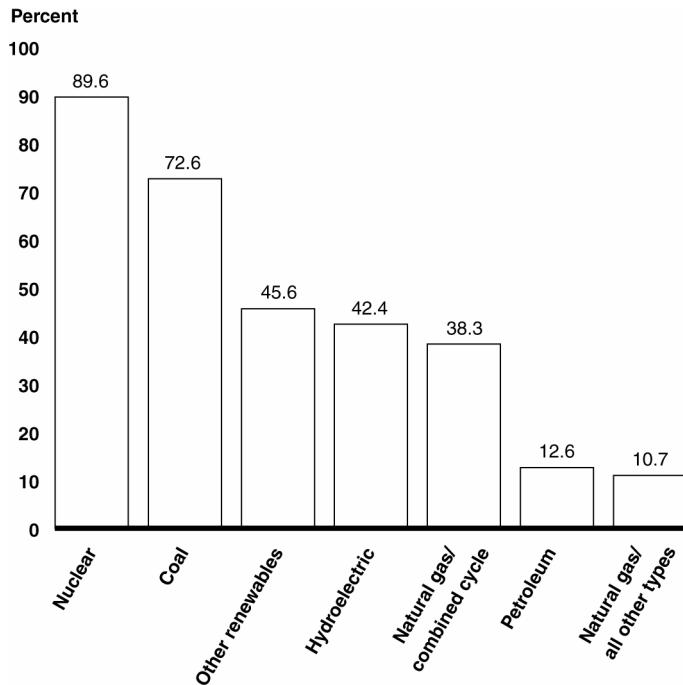
Even with sufficient supply and storage capacity, stakeholders said that it would be more feasible and cost-effective to construct new natural gas units or dispatch excess capacity at existing natural gas units instead of fuel switching. Converting a coal-burning plant to natural gas would involve significant capital costs and result in a less efficient plant with higher operating costs. At a minimum, an existing boiler designed for coal would need a new combustion system and a new heating surface to account for the differences between coal and gas combustion, according to stakeholders. Because a gas-fired steam generator is designed differently from a coal-fired boiler, burning natural gas in a coal-fired boiler would result in a loss of efficiency, which could decrease the amount of electricity produced by the unit. According to one stakeholder, a decrease in capacity of 10 to 12 percent is a reasonable estimate. As a result, certain stakeholders said that it would be more economically efficient in terms of capital and fuel costs to tear down an existing coal unit and build a new natural gas unit instead of retrofitting an existing coal unit to burn natural gas. In addition, industry stakeholders said that some coal-fired units cannot switch fuels because natural gas is not available, existing technology cannot be modified, or the system reserve is so low in the area that shutting down the coal plant for conversion to natural gas would result in brownouts or blackouts. One stakeholder stated that modifying a coal unit to burn natural gas would take the unit out of service for 4 to 6 months.

In the few instances in which the industry has switched from coal to gas, existing plants have not been retrofitted to burn gas; instead, existing gas-fired units have displaced generation from marginally cost-effective coal-fired units rather than retrofitting existing plants to burn gas. Industry stakeholders said that many natural-gas-fired power plants were constructed in the late 1990s and early 2000s, leading to a large amount of underutilized capacity at plants constructed during this boom. According to one stakeholder, it is likely that, instead of fuel switching at coal plants, utilities would dispatch these underutilized natural gas units and run coal units less aggressively. EIA data describing the average capacity factors of different generation options demonstrate that significant excess capacity exists at natural-gas-fired plants. Capacity factor, in general terms, measures how intensely and frequently a generating unit is run.¹¹ According to EIA, the average capacity factor for natural gas units is much lower than capacity factors for other generation options, such as nuclear and coal. As illustrated in figure 4, nuclear and coal-fired generation have the highest average capacity factors for 2006 at 89.6 percent and 72.6 percent, respectively. As a result, coal and nuclear capacity serve base load energy requirements.¹² In 2006, average capacity factors for natural gas units ranged from 38.5 to 10.7 percent, depending upon the specific type of natural gas unit. Accordingly, there is potential to increase the utilization of existing natural gas units. Furthermore, the fact that there is excess capacity at existing natural gas units demonstrates the economic and other barriers to using natural gas for electricity production.

¹¹The EIA definition of capacity factor is “the ratio of the electrical energy produced by a generating unit for the period of time considered to be the electrical energy that could have been produced at continuous full power operation during the same period.”

¹²EIA defines base load capacity as the generating equipment normally operated to serve loads on an around-the-clock basis. According to EIA, a base load plant usually houses high-efficiency, steam-electric units, which are normally operated to take all or part of the minimum load of a system, and which consequently produce electricity at an essentially constant rate and run continuously. These units are operated to maximize system mechanical and thermal efficiency and minimize system operating costs.

Figure 4: Average Capacity Factor by Energy Source, 2006



Source: Energy Information Administration, Form EIA-860, "Annual Electric Generator Report;" Form EIA-906, "Power Plant Report;" and Form EIA-920, "Combined Heat and Power Plant Report."

In the event that the owners or operators of a plant decided to switch from coal to natural gas, changes to infrastructure, including pipelines and individual electricity-generating units, would require regulatory approval, which can be costly and time-consuming to obtain. Certain stakeholders said that it may take years to complete all of the mandatory permitting requirements before constructing pipelines. One stakeholder had significant reservations about whether the industry could obtain the required permits and rights-of-way for such an undertaking. However, this stakeholder also said that the natural gas industry may acquire rights-of-way by eminent domain rights, which could help address pipeline-siting and construction challenges. Stakeholders also identified air quality issues as a concern in retrofitting a coal plant to burn natural gas. Modifying the equipment at an existing coal plant could trigger permitting requirements and necessitate the purchase of additional air pollution control technologies. Several stakeholders said that modifying air permits would not be difficult, but that it would take time for the regulatory agencies to review the applications and issue revised permits.

Fuel Costs and Electricity Prices Could Increase As a Result of Fuel Switching, among Other Adverse Economic Consequences

Fuel switching and related pressure on available natural gas supplies could increase the price of natural gas, increasing energy costs for residential, commercial, and industrial consumers for both natural gas and electricity. Because energy costs

account for a relatively large share of overall costs or because they are heavily dependent on natural gas, for some residential and industrial consumers, any price increases can present significant difficulties. According to industry stakeholders, higher natural gas prices would affect millions of residential consumers who cook and heat their homes and water with natural gas. In 2006, we reported that the effect of higher wholesale natural gas prices on consumers depends largely on the degree to which the consumers or their suppliers may have purchased gas on the spot market—which reflects current wholesale prices—or may have taken steps to reduce their exposure to these prices.¹³ The effect of higher prices also depends on the consumer's sensitivity to price changes. Some consumers, such as low-income residents and certain high-energy intensive industries, are more sensitive to price changes than others and appear likely to experience the greatest impact.

As we reported in 2006, high natural gas prices adversely affected industrial consumers. In particular, industries that rely on natural gas, such as chemical and fertilizer manufacturers, could face increased fuel costs. Other affected industries could include iron, steel, automobile manufacturing, glass, aluminum, plastics, paper and machinery, according to industry stakeholders. High fuel costs could make these industries less competitive internationally, according to stakeholders. Recent high natural gas prices forced some industrial consumers to shut down production facilities, and further cutbacks could occur if prices are high in the future.

According to industry stakeholders, increases in the price of natural gas could also lead to electricity price increases. In the late 1990s and early 2000s, the combination of low gas prices and the fact that natural gas produces less air pollution than coal led to the construction of many new natural gas plants. However, these plants are currently underutilized because gas prices have risen substantially in recent years. Requirements to utilize these plants instead of coal plants could lead to higher electricity costs for consumers because some producers would be able to pass on their increased operating costs to consumers.

Potential Benefits of Fuel Switching Include Reductions in Emissions and in Some Operation and Maintenance Costs, and Improvements in Local Environmental Benefits

Switching from coal to natural gas could decrease airborne emissions of carbon dioxide and air pollutants that cause adverse health effects, including nitrous oxide, sulfur dioxide, and particulates. Natural gas is the cleanest fossil fuel to burn in terms of air quality and carbon emissions, emitting up to 60 percent less carbon dioxide than coal when burned, according to industry stakeholders. However, stakeholders said that the magnitude of these benefits would depend on the source of the natural gas and other factors, such as plant efficiency. For example, one stakeholder said that increased reliance on LNG would result in smaller carbon dioxide emission reductions relative to coal than those through production and

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

consumption of domestic natural gas because of the carbon dioxide emissions associated with the processing and transportation of imported LNG. In addition, utilities switching from coal to natural gas could gain public relations benefits from emission reductions, as well as a potential advantage associated with early action toward compliance with any future emissions reductions policies.

Fuel switching from coal to natural gas could also decrease some operations and maintenance costs, in addition to lessening the physical impact on the surrounding environment. For example, fuel switching to natural gas would decrease the costs of storing coal on site and grinding it in preparation for combustion. In addition, according to one stakeholder, natural gas infrastructure has less of an impact on the surrounding environment because plants are modular and have smaller footprints than coal-burning facilities. Also, natural gas is delivered by pipelines, which are less visible than the infrastructure required for transporting and storing coal, particularly in urban areas, because they are often buried.

Conclusions

Burning natural gas instead of coal at CPP and at electricity-generating units nationwide as part of efforts to reduce greenhouse gas emissions involves important tradeoffs related to economic, environmental, infrastructure, and fuel supply considerations. While CPP can adjust its fuel mix to burn more natural gas, doing so at existing electricity-generating units nationwide poses substantial challenges because of fuel supply constraints, infrastructure that would require modification, and economic considerations.

With respect to fuel switching at CPP, AOC's plans to purchase more natural gas than necessary under the Green the Capitol initiative raises questions about the efficient use of appropriated funds. Specifically, we estimated that fuel switching at the plant should cost between \$1.0 and \$1.8 million in 2008, well below the \$2.75 million budgeted for this purpose. Key uncertainties with our estimates include the future price of each fossil fuel burned at the plant and the lack of complete, reliable information on the overall efficiency of the plant or its seven boilers. Based on our estimates, substituting natural gas for a portion of the coal used at the plant would achieve reductions in carbon dioxide emissions at a cost of about \$139 per ton of emissions. We believe that any decisions to exceed the level of fuel switching called for by the initiative should take into consideration the sense of the Congress with respect to achieving greenhouse gas reductions at the plant, as well as the economic and environmental tradeoffs associated with the use of each fuel.

Recommendation for Executive Action

We are recommending that, before adjusting the Capitol Power Plant's fuel mix beyond the level directed by the Green the Capitol initiative, the Acting Architect of the Capitol consult with AOC's oversight committees in the Congress and evaluate the economic and environmental trade-offs associated with the use of each fuel at the

plant, taking into account the efficiency of the plant's boilers, related fuel supply systems, and pollution control equipment.

Agency Comments and Our Evaluation

We provided a draft copy of this report to the Acting Architect of the Capitol for review and comment. AOC provided comments via electronic mail. AOC officials said that they agreed with our cost estimate under the high fuel price scenario but that they were concerned about the potential level of resources that would be required to respond to our recommendation. We subsequently met with AOC officials who said that they were concerned that implementing our recommendation would require them to collect exact information on the efficiency of its boilers and fuel supply systems. Based on this discussion, we adjusted the wording of the recommendation to clarify that this was not our intent. AOC also provided a number of technical clarifications regarding the plant's operation and their cost estimates for fuel switching, which we incorporated into our report as appropriate.

We are sending copies of this report to the appropriate congressional committees. We are also sending this report to the Architect of the Capitol and the Department of Energy. We will make copies available to others upon request. In addition, this report will be available at no cost on the GAO Web site at <http://www.gao.gov>.

If you or your staffs have any questions about this report, please contact Terrell Dorn at (202) 512-6923 or dornt@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 major contributions to this report are listed in enclosure II.



Terrell Dorn, Director
Physical Infrastructure Issues



Frank Rusco, Director
National Resources And Environment

Enclosures

Enclosure I: Scope and Methodology

To respond to the first objective, we reviewed two analyses prepared for the House of Representatives' Chief Administrative Officer (CAO), including an analysis prepared by the Architect of the Capitol (AOC) that served as the basis for the fuel-switching funding in the Capitol Power Plant's (CPP) fiscal year 2008 appropriation, and a subsequent analysis prepared by the Department of Energy's Lawrence Berkeley National Laboratory (LBNL). We then developed our own analysis based on data provided by AOC and U.S. Energy Information Administration (EIA). Part of our analysis was consistent with LBNL's approach. The primary differences are that we extended LBNL's analysis to future years based on projections of fuel use and prices.

In conducting our analysis, we relied on fuel input data from AOC that had been provided to LBNL via AOC's "Utilities Guru" database. In its analysis, LBNL had converted the fuel quantities from physical units to thermal units (expressed in millions of British thermal units). Next, we estimated the portion of steam produced by CPP that is used to heat House buildings. To do this, we divided the total square footage of House buildings by the total square footage served by the plant, based on data from the AOC's 2006 Report to Congress.¹⁴ We excluded the Ford House Office Building from our analysis because its steam is supplied by General Services Administration, not CPP. The resulting calculation indicated that approximately 29 percent of the plant's steam output is attributable to the House of Representatives.

Because the initiative recommends that CPP use natural gas to meet the energy needs of the House, we assumed that the House's 29 percent of steam would be provided by natural gas only. We added to this an amount of natural gas equivalent to 71 percent of the total natural gas used had the fuel switching not occurred. This last step ensures that the amount of natural gas is "additional" to what would have occurred in a business-as-usual scenario. We based our business-as-usual scenario on the plant's historical average of 43 percent natural gas, 47 percent coal, and 10 percent fuel oil over the period from 2001 through 2007. We left the amount of fuel oil used unchanged because the plant's operations require the use of fuel oil as a back-up fuel. These calculations enabled us to approximate the level of natural gas required to meet the initiative's directive in fiscal year 2008.

To calculate the incremental cost of the new fuel mix in fiscal year 2008, we estimated the total cost of fuel under the Green the Capital scenario and subtracted our estimate of fuel cost under the business-as-usual scenario. For both scenarios, we multiplied the quantities of fuels needed by our estimates of the average cost of fuel per unit. We based our estimates of the average cost per unit for each fuel on fiscal year 2008 price projections from EIA. We escalated the EIA-projected prices by percentage "premiums" based on estimated relationships between average U.S. fuel

¹⁴The buildings used by the House of Representatives that were included in our analysis are: Cannon House Office Building, Longworth House Office Building, Rayburn House Office Building, East and West underground garages, and the House Page Dorm. Our analysis also includes 50 percent of the U.S. Capitol building and CPP.

prices in the industrial sector, as reported by EIA, and AOC's annual average fuel costs per unit over the period from 2001 through 2007.

We assumed that each boiler at the plant converts fuel into steam with equal efficiency based on a review of available data from an independent consultant to GAO and from Ross Associates, a consultant to AOC. We also requested information from AOC on the efficiency of its boilers on three occasions between November 2007 and January 2008. In January 2008, AOC referred us to the Ross Associates analysis. In April 2008, AOC provided data on the combustion efficiency of its coal boilers and two of the four boilers that can burn oil or natural gas, which it collected during February 2008. Because AOC did not make us aware of this analysis or provide any results until after we had completed our work, time constraints precluded us from assessing its reliability or including it in our analysis. A review of the data suggests that it would not have made a material difference in our cost estimates.

As part of our analysis, we projected the AOC's per unit costs of natural gas, coal, and fuel oil for CPP for the period from 2008 through 2012. To estimate a baseline level of fuel consumption for the years 2008 through 2012, we started with the average fuel consumption by CPP during fiscal years 2001 through 2007. We then applied a 1 percent decline in demand each year, beginning in 2008. The 1 percent estimate is based on two partially offsetting factors:

- Additions to the Capitol Complex, including the Capitol Visitor Center, are expected to increase the plant's steam demand by 1 percent each year through 2025. This estimate was obtained from a 2004 report developed by an AOC consultant.
- The Energy Policy Act of 2005 requires a 2 percent reduction in energy use per year for federal buildings. Because over one-quarter of House energy use is for heating, the act's implementation may significantly reduce steam demand over time.

Next, we estimated the incremental cost of the fuel mix under a Green the Capitol scenario over what the cost would be without a policy change, for each year between 2008 through 2012. To do so, we used EIA-projected fuel prices for the industrial sector escalated with our estimated AOC cost premiums. These calculations produced a baseline cost scenario for each year, ranging from a high of \$1.44 million in fiscal year 2009 to a low of \$1.15 million in fiscal year 2012.

We also conducted sensitivity analyses around our baseline estimates using a low-price and a high-price scenario for fiscal years 2008 to 2012. EIA has not yet published new low- and high-price projections because of their recent revision of the Annual Energy Outlook 2008. To estimate low- and high-price projections, we adjusted the EIA projections of fuel prices for the industrial sector using measures of variability of these prices in the last few years. Specifically, we calculated the

coefficient of variation¹⁵ of monthly prices of coal, natural gas, and distillate oil in the U.S. industrial sector over the period of December 2003 through November 2007.¹⁶ The coefficient of variation for the monthly prices for this period were: 18.2 percent for the price of natural gas, 6.5 percent for coal, and 17.2 percent for fuel oil. For the low price scenario, we reduced EIA's price projections for each of the three fuels by the corresponding percentage, while for the high-price scenario, we escalated the price projections by the same percentages.

All of our cost estimates are in constant 2006 dollar values. In preparing our estimates, we consulted with AOC staff, officials representing the House CAO, and the Department of Energy (including LBNL and EIA). We also reviewed relevant studies prepared by these agencies.

To respond to the second objective, we analyzed available data from the Department of Energy and other sources. We also obtained information from key stakeholders identified in discussions with the department that represent the electricity generation, natural gas, and coal industries using written interview questions. These key stakeholders included the American Gas Association (AGA), Edison Electric Institute (EEI), Electric Power Research Institute (EPRI), Interstate Natural Gas Association of America (INGAA), National Coal Council (NCC), National Mining Association (NMA), and Natural Gas Supply Association (NGSA). We conducted our work between October 2007 and April 2008 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.

¹⁵The coefficient of variation is defined as the standard deviation divided by the mean.

¹⁶At the time of writing, December 2007 was the last month for which prices of these fuels were available from EIA.

Enclosure II: GAO Contacts and Staff Acknowledgments

GAO Contacts

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Staff Acknowledgments

In addition to the contacts named above, Elizabeth Beardsley, Janice Ceperich, Tonnye Conner-White, Elizabeth R. Eisenstadt, Philip Farah, Mark Gaffigan, Michael Hix, Hannah Laufe, Jessica Lemke, Jon Ludwigson, Susan Michal-Smith, SaraAnn Moessbauer, Joseph Thompson, and Sara Vermillion made key contributions to this report.

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