Evaluation of Future Strategic and Energy Efficient Options for the U.S. Capitol Power Plant

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Board on Infrastructure and the Constructed Environment

Division on Engineering and Physical Sciences

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The authoring committee acknowledges the significant contributions made by all of the workshop participants, who willingly and enthusiastically volunteered their time and ideas.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We thank the following individuals for their review of this report:

Lionel Barthold, Power Technologies, Inc. (retired),
Daniel Coyle, Thermal Engineering Group, Inc.,
James Markowsky, American Electric Power Service Corporation (retired),
Robert McKim, Trenchless Technology Center, Louisiana Tech,
Get Moy, AECOM,
David Skiven, General Motors Worldwide Facilities Group (retired),
Amanda Staudt, National Wildlife Foundation,
Stanley Suboleski, Consultant,
Michael Telson, University of California.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Chris G. Whipple, ENVIRON International Corporation. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Contents

Summary

The U.S. Capitol Complex in Washington, D.C., comprises some of the most historic, symbolic, and heavily used buildings in the nation. Among these are the U.S. Capitol, the Supreme Court, the Library of Congress, the House and Senate office buildings, the U.S. Botanic Gardens, the Capitol Visitors Center, and various support facilities. Within these buildings, public policy is made, legislation is enacted, and priceless artifacts and documents are stored and displayed. They are the workplaces of 535 congressional representatives, the justices of the Supreme Court, their staffs, the staff of the Library of Congress, and others and are the destination of millions of people from around the world. Reliable, secure utilities to heat, cool, and power these buildings are essential to the functions carried out within them.

The steam and chilled water required to heat and cool these buildings and related equipment are generated and distributed by the Capitol Power Plant (CPP[1]) district energy system.[2] The CPP system includes a steam plant, two refrigeration plants, administrative buildings, a coal yard, and more than 3 miles of tunnels and trenches located beneath city streets and neighborhoods. Steam is generated through seven boilers that burn a combination of low-sulfur coal, natural gas, and fuel oil.

The Office of the Architect of the Capitol (AOC) is responsible for oversight of the Capitol Complex and the CPP.

Today, the CPP accounts for more than 30 percent of the total energy consumption and 37 percent of the greenhouse gas emissions attributable to the U.S. Capitol Complex. The condition of the tunnel system is deteriorating. Complaints of unsafe working conditions in the tunnels arose as a result of falling concrete, asbestos, and extreme heat, as well as the lack of communication systems, lighting, and adequate egress for workers in an emergency.

Portions of the CPP and the tunnels are 50 to 100 years old and are reaching the end of their useful lives. They require an investment of hundreds of millions of dollars or more to provide reliable, secure utility services to the U.S. Capitol Complex for the foreseeable future. With growing public concern about improved energy efficiency, reduction of greenhouse gas emissions, and reduced dependence on imported oil, the renewal of the CPP and its distribution network presents a significant opportunity to showcase energy-efficient technologies and lead the nation by example.

In 2008, the AOC requested that the National Research Council (NRC) appoint an ad hoc committee to (1) evaluate publicly available consultant-generated options for the delivery of utility services to the U.S. Capitol Complex and (2) recommend how the Capitol Power Plant can be best positioned to meet the future strategic and energy efficiency requirements of the U.S. Capitol Complex. The AOC specifically requested that the committee act as a second-level reality check against fatal flaws in the AOC methodology or strategic development.

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[1] The Capitol Power Plant stopped producing electricity in the 1950s; electricity for the U.S. Capitol Complex is supplied by the Potomac Electric Power Company (PEPCO).

[2] A district energy system produces steam, hot water, or chilled water at a central plant and distributes them out to buildings in the district for space heating, domestic hot water heating, and air conditioning. A system of this type eliminates the need for individual buildings to have their own boilers or furnaces, chillers, or condensers for air conditioners.

COMMITTEE'S APPROACH

This report of the Committee on the Evaluation of Future Strategic and Energy Efficient Alternatives for the U.S. Capitol Power Plant (see Appendix A) is based on the AOC's and its consultants' presentations at two committee meetings, including a workshop (see Appendixes B and C); the report entitled *Strategic Long Term Energy Plan 70% Report* (hereinafter referred to as the 70% Report), (AOC, 2009); and a brief oral presentation of the utility service distribution options.

The 70% Report is an interim report that is still subject to additions and revisions. It includes the background information on the existing CPP and its operations and presents 10 primary options for the CPP, its tunnel distribution system, and "non-CPP" distributed options. The options analyzed for the CPP include the existing configuration with three options for fuel mix; combined heat and power (co-generation); construction of a new plant; and the use of a range of technologies, including fuel cells, coal gasification, heat recovery chillers, waste-to-energy, and high-temperature water.

In response to committee comments at its first meeting on December 4 and 5, 2008, the AOC contracted for an analysis of carbon dioxide (CO_2) and hazardous air pollutant emissions for each of the options. The results of the analysis were presented at the committee's March 12, 2009, workshop. No additional studies were available to the committee.

FINDINGS

Within the parameters of the 70% Report, the committee did not find any fatal flaws in the analyses presented.

The committee was impressed with the competence and dedication of the AOC staff, which provided the committee as much operating data as it could within the security limitations in force. It was clear that the AOC staff was sincerely seeking feedback from the committee and is willing to improve the outcome of the planning effort.

The committee was also impressed with the consulting teams for the number of options (17) for the CPP plant and the distribution systems considered in the 70% Report. The consulting teams demonstrated considerable knowledge of and experience in the types of systems that exist to serve the U.S. Capitol Complex and the technologies that are current and viable.

Regarding the 70% Report, the committee has three overarching findings:

- First, the 70% Report makes no mention of the unique characteristics of the U.S. Capitol Complex and of the opportunities presented to serve as an example to the nation.
- Second, based on the material in the 70% Report and two face-to-face meetings, the committee provided recommendations to bring the 70% Report to 100 percent completion, including suggestions for additional analyses and for the development of indices to evaluate the options.
- Third, all options presented in the 70% Report retain essentially all of the institutional, environmental, political, and economic constraints under which the CPP and the distribution system currently operate. This approach necessarily limits the choice of options and may preclude the consideration of more creative options that could result in improved solutions.

Among the shortcomings in the 70% Report are the following:

1. Lack of a clear statement of assessment criteria for the options presented;
2. Lack of a holistic systems approach;
3. Acceptance of all current constraints as immutable;
4. Acceptance of all current relationships as permanently binding; and
5. Demand projections that are not supported by firm data and are not reflective of applicable mandates for energy consumption reduction.

RECOMMENDATIONS

In order to bring the 70% Report to 100 percent completion as the Strategic Long-Term Energy Plan for the U.S. Capitol Complex and to support and justify the consultants' recommendations for the preferred option(s), the committee recommends additional work in eight strategic areas, as follows:

1. Articulate the methodology used for evaluating and selecting the option(s);
2. Develop additional indices to be used to evaluate the options;
3. Integrate the construction phasing with the energy demand planning horizons;
4. Conduct more comprehensive environmental evaluations of the options;
5. Evaluate the likelihood that the options would meet regulatory requirements;
6. Perform sensitivity analyses for different CO_2 allowances and fuel availabilities and prices, given the uncertainty of future greenhouse gas regulations and energy supplies and prices;
7. Evaluate distribution tunnel layouts; and
8. Summarize the results and rationale for the selected option(s).

In regard to the committee's broader charge of recommending how the CPP can be best positioned to meet the future strategic and energy efficiency requirements of the U.S. Capitol Complex, the committee recommends that additional analyses be performed in six areas as follows:

1. *Reliability and risk assessments:* Conduct a comprehensive risk analysis of each viable alternative to ascertain that it is capable of continuously generating and delivering the required services.
2. *Comparative demand and supply projections:* Develop a strategic decision making tool to aid the Congress and the AOC in planning and seeking funding for the upgrading of the CPP and the utility distribution system.
3. *Workforce demand evaluations:* Evaluate the implications for labor costs, skills, training, and staffing of operational changes in the CPP and the distribution system.
4. *Exploration of a wider range of technologies:* Undertake a study of technologies that may become warrantable in the next 25 years.
5. *Benchmarking:* Develop a plan for measuring the performance of the CPP, using benchmarks for efficiency, environmental compliance, and other measures.
6. *Response to shortcomings identified:* Review the shortcomings that have not been explicitly addressed as recommendations and develop an action plan to address those shortcomings the AOC considers material.

The common theme of these additional analyses is to differentiate the unique attributes of the U.S. Capitol Complex and the CPP infrastructure project from typical district energy projects, and to seize the opportunity for setting an example for the nation in regard to energy reliability, efficiency, cost-effectiveness, security, and environmental stewardship.

1
Introduction

The U.S. Capitol Complex in Washington, D.C. comprises some of the most historic, symbolic, and heavily used buildings in the nation. Among these are the U.S. Capitol, the Supreme Court, the Library of Congress, the House and Senate office buildings, the U.S. Botanic Gardens, the Capitol Visitors Center, and various support facilities (Figures 1.1 and 1.2). Within these buildings, national public policy is made, legislation is enacted, and priceless artifacts and historic documents are stored and displayed. Each year these facilities are visited by millions of people from around the world. They also serve as the workplaces of 535 congressional representatives, the justices of the Supreme Court, their staffs, the staff of the Library of Congress, and others.

FIGURE 1.1 U.S. Capitol Building, the Supreme Court, the Library of Congress, and the Capitol Complex surroundings. SOURCE: AOC Web Site.

The special nature of the U.S. Capitol Complex and its many and diverse stakeholders create a unique context for decision making about the future requirements of the Capitol Power Plant. Political and environmental factors are major elements, as indicated by the Green the Capitol Initiative (Beard, 2007) and the interests of residents in neighborhoods surrounding the Complex and the CPP. Physical factors, such as space constraints for the CPP and the distribution system, also strongly influence decision making about them. Other significant influences include rapid changes in potentially appropriate energy technologies, and funding challenges.

The responsibility for operating and maintaining the U.S. Capitol Complex lies with the Office of the Architect of the Capitol (AOC).[1] The CPP operates 24 hours per day, 365 days per

[1] The AOC is responsible to the United States Congress for the maintenance, operation, development, and preservation of the U.S. Capitol Complex, which includes the Capitol, the congressional office buildings,

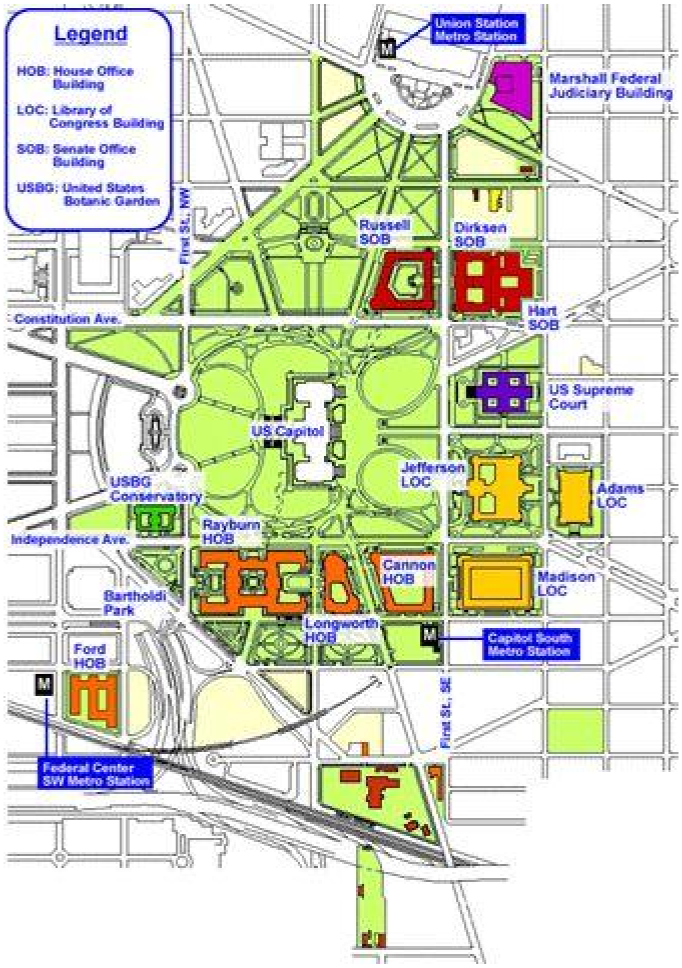

FIGURE 1.2 Map of the U.S. Capitol Complex. (The Capitol Power Plant is at the bottom of the map, north of the CSX railroad tracks, and the coal yard is south of the railroad tracks.) SOURCE: AOC Web site.

year to generate the steam and chilled water required to heat and cool these buildings and related equipment. Steam and chilled water in turn are distributed to the individual buildings through utility lines contained within more than 3 miles of tunnels and trenches located beneath city streets and neighborhoods.[2]

Originally built in 1909 to supply steam and electricity[3] to the U.S. Capitol, the CPP has been expanded in a decades-long process to provide utility services to about 19 million square feet of space, including the Government Printing Office and Union Station[4] (Figure 1.3).

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the Library of Congress buildings, the Supreme Court building, the U.S. Botanic Garden, the Capitol Power Plant, and other facilities.

[2] The tunnels also carry other utilities, including fiber optic and telephone lines.

[3] The CPP stopped producing electricity in the 1950s; electricity is now supplied to the U.S. Capitol Complex by the Potomac Electric Power Company (PEPCO).

[4] The Government Printing Office and Union Station are not part of the U.S. Capitol Complex per se, but they are served by the CPP district energy system.

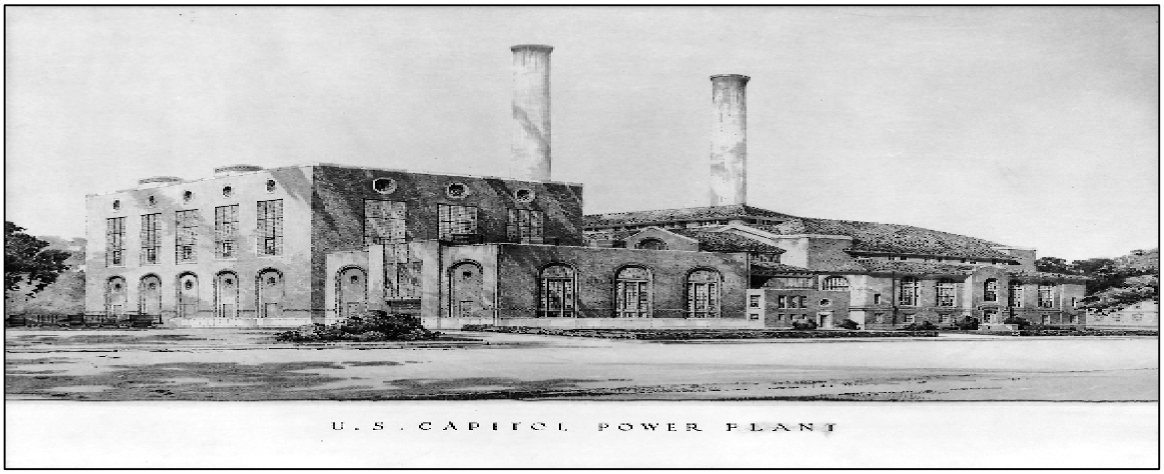

FIGURE 1.3 Capitol Power Plant circa 1909. SOURCE: AOC.

FIGURE 1.4 Site plan of Capitol Power Plant. SOURCE: AOC.

Today, the CPP district energy system[5] includes a steam plant, two refrigeration plants, administrative buildings, a coal yard, and 3 miles of distribution tunnels that carry the steam and chilled water pipes from the plant to the various buildings (Figure 1.4).

The condition of the distribution tunnels, which are 50 to 100 years old, is deteriorating. Complaints of unsafe working conditions in the tunnels arose as a result of hazards such as falling concrete, asbestos, and extreme heat, as well as the lack of communication systems, lighting, and adequate egress in an emergency. In 2006, the AOC issued its Utility Tunnel Improvement Plan as directed by the House Committee on Appropriations. Actions are being taken to abate the identified hazards including asbestos, and additional updating activities are ongoing. Agreements were negotiated with the Office of Compliance specifying maximum distances between points of

[5] A district energy system produces steam, hot water, or chilled water at a central plant and then pipes them out to buildings in the district for space heating, domestic hot water heating, and air conditioning. A system of this type eliminates the need for individual buildings to have their own boilers or furnaces, chillers, or condensers for air conditioners.

FIGURE 1.5. Workers inside one of the CPP tunnels. SOURCE: AOC.

egress and other conditions related to worker safety (Figure 1.5) (GAO, 2006).

At the CPP, steam is generated through seven boilers that burn a combination of low-sulfur coal, natural gas, and fuel oil. The plant has the flexibility to switch among three different fuel types or burn a combination of fuels. Thus, in the event of supply disruptions or price fluctuations, the AOC can adjust the mix of fuels being used to continue providing reliable utilities without interruption. Currently, the CPP accounts for more than 30 percent of the total energy consumption and 37 percent of the greenhouse gas emissions attributable to the U.S. Capitol Complex (GAO, 2008).

In 2007, the AOC completed the construction of the new West Refrigeration Plant Expansion Project, which included the installation of new, high-efficiency chillers, pumps, and cooling towers and included the use of environmentally friendly 134-A refrigerant. The following year, new control systems were installed on several boilers to improve equipment operability and efficiency.

The CPP operates under the Title V permitting program established under the Environmental Protection Agency's (EPA's) 1990 Clean Air Act Amendments. The Title V program requires all new and existing major sources of air emissions to obtain a federally approved, state-administered operating permit. The Title V operating permit includes all applicable requirements from federal and state air emission regulations with which the CPP is required to comply. The Title V operating permit currently held by the AOC is administered through the District of Columbia's Department of Health, Air Quality Division. In addition, the CPP has a continuous emissions monitoring system in place, requiring quarterly certification by the AOC and annual certification by an independent third-party testing firm. The AOC must submit quarterly emissions monitoring certification reports to the District of Columbia and semi-annual and annual Title V compliance certification reports to the Director of EPA Region III.

In the last several years, the Energy Policy Act of 2005 (P.L. 109-58), the Energy Independence and Security Act of 2007 (P.L. 110-140), and the Green the Capitol Initiative (Beard, 2007) have directly impacted the requirements for energy efficiency for the CPP and its environmental footprint. The Energy Independence and Security Act of 2007 requires federal agencies to reduce their greenhouse gas emissions for new and existing buildings by 2030. That act also specifically requires the AOC to take such steps as necessary to operate the steam boilers and the chillers of the CPP in the most energy-efficient manner possible to minimize carbon emissions and operating costs.[6]

The Green the Capitol Initiative (Beard, 2007) is intended to reduce the environmental impacts associated with the operation of the House of Representatives' buildings, to provide an environmentally responsible and healthy indoor environment, and to serve as a showcase for sustainability. The initiative calls for the House of Representatives to operate in a carbon-neutral manner (defined as producing no net contribution to greenhouse gas emissions) by December 2008.[7]

To improve and advance the operations and long-term viability of the CPP and the utility distribution system, and to develop a long-term strategic plan, the AOC contracted for an assessment of district energy technologies. The consultants were asked to (1) analyze current operations at the CPP; (2) propose options for the future delivery of utility services to the U.S. Capitol Complex; (3) compare the viability, energy efficiency, emissions, operational costs, and capital costs of each option against current operations (base case) and 10 other options; and (4) develop short-term recommendations to increase the efficiency of the CPP, reduce its operational costs, and reduce its environmental impact.

The AOC contracted for a second study to analyze the long-term use of the existing tunnels and nine options for the future layout of the tunnel system.

Because both the CPP and its tunnel distribution system are reaching the end of their useful lives, they require significant investments to continue providing reliable and secure utilities to the U.S. Capitol Complex for the foreseeable future. With the mounting public concern for improved energy efficiency, reduction of greenhouse gas emissions, and reduced dependence on imported oil, the renewal of the CPP and its distribution network present a significant opportunity to showcase energy efficient technologies and lead the nation by example.

STATEMENT OF TASK

In 2008, the AOC requested that the NRC appoint an ad hoc committee to (1) evaluate a set of publicly available, consultant-generated options for the delivery of utility services to the U.S. Capitol Complex and (2) recommend how the Capitol Power Plant can be best positioned to meet the future strategic and energy efficiency requirements of the U.S. Capitol Complex. The nine members of the committee have worked in government, industry, and academia. Their combined expertise includes the design, operation, and renovation of district energy systems; utility master planning; alternative/advanced energy systems; sustainable design; engineering; plant construction; tunneling methods and technologies; risk analysis; and environmental and economic analysis of energy systems (Appendix A contains biosketches of the committee).

THE COMMITTEE'S APPROACH

The committee held its first meeting on December 4 and 5, 2008, in Washington, D.C. At that meeting, AOC staff and its consultants presented information about the operations of the CPP, the 10 consultant-generated options for steam and chilled water delivery, and options for the layout of the tunnel distribution system. After touring the CPP, the committee provided verbal comments. The AOC and its consultants used the committee's comments to expand the range of aspects to consider, narrow down the number of options, and provide new information about the

[6] Additional legislation has been proposed that could impose additional requirements regarding greenhouse gas emissions.
[7] A letter from the Chief Administrative Officer dated December 2008 states that the goal was reached and that the House reduced its carbon footprint by 74 percent (Beard, 2008).

carbon and hazardous air pollutant emissions aspects of the options.

The committee held its second meeting on March 12 and 13, 2009. To aid in its evaluation, the committee invited additional experts to participate in a 1-day workshop focused on the revised set of consultant-generated options, including an analysis of carbon and hazardous air pollutant emissions for each CPP option. (Appendix B contains biosketches of the participants invited, and Appendix C includes the meeting dates and agendas.)

The committee's report is based on the AOC's and consultants' presentations at the two committee meetings, including the workshop; the report entitled *Strategic Long Term Energy Plan 70% Report* (hereinafter referred to as the 70% Report) (AOC, 2009) covering the background information and the CPP and tunnel options; and a brief oral presentation of the utility service distribution options. No additional studies were available to the committee.[8] The committee's report also benefits from the discussions at the workshop and the committee members' own expertise. Finally, the report was peer-reviewed in accord with NRC procedures.

The 70% Report is an interim report that is still subject to revisions. It includes the background information on the existing CPP and its operations and presents 17 options for the CPP and its tunnel distribution system. The options analyzed for the CPP included the existing configuration with three options for fuel mix; combined heat and power (co-generation); construction of a new plant; and the use of a range of technologies, including fuel cells, coal gasification, heat recovery chillers, waste-to-energy, and high temperature water.[9]

The committee's findings and recommendations are presented in Chapters 2 and 3. Chapter 2 responds to the charge to the committee to "evaluate publicly available, consultant-generated options for the delivery of utility services to the U.S. Capitol Complex." It addresses the options presented to the committee in terms of (a) the strengths identified; (b) the shortcomings identified; and (c) the additional work that the committee recommends for the completion of the final or 100 percent *Strategic Long Term Energy Plan.*

Chapter 3 responds to the more global charge of "recommend[ing] how the Capitol Power Plant can be best positioned to meet the future strategic and energy efficiency requirements of the U.S. Capitol Complex." To that effect, it presents the committee's recommendations for work that could be undertaken to correct and update the key energy infrastructure of the U.S. Capitol Complex, seizing the opportunity for setting an example for the entire country in energy reliability, efficiency, cost effectiveness, security, and for environmental stewardship.

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[8] Although the committee also received copies of the "Capitol Complex Master Plan, Sustainability Framework Plan," there was insufficient time available to review or discuss it in the meetings.

[9] Committee members expressed an interest in informally reviewing the final report.

2
Evaluation of Consultant-Generated Options

The committee makes three general statements at the outset:

- First, several committee members noted at both meetings that the 70% Report (AOC, 2009) makes no mention of the unique characteristics of the U.S. Capitol Complex and of the opportunities presented to serve as an example to the nation.
- Second, based on the material in the 70% Report and two face-to-face meetings, the committee provided recommendations to bring the 70% Report to 100 percent completion, including suggestions for additional analyses and for the development of indices to evaluate the options.
- Third, all options presented in the 70% Report retain essentially all of the institutional, environmental, political, and economic constraints under which the CPP and the distribution system currently operate. This issue is taken up later in this chapter.

STRENGTHS IDENTIFIED BY THE COMMITTEE

This section describes strengths that the committee noted in its review of the 70% Report, in its tour of the CPP, and in the presentations by the AOC staff and the consultants.

AOC Staff

The committee was impressed with the competence and dedication of the AOC staff, especially in consideration of the challenges being faced. It was clear that the staff was sincerely seeking feedback from the committee and is willing to improve the outcome of the planning effort. This has been clearly demonstrated by the additional work evaluating CO_2 and hazardous air pollutant emissions that was completed between the first and second committee meetings.

The challenges for the AOC staff include providing critical utilities services with a partially obsolete infrastructure; responding to its various and diverse constituents; and the sheer magnitude of the changes required to move the infrastructure into the new energy environment of the 21st century. The staff has recognized the many constraints on the CPP and has focused its efforts on providing highly reliable utility services to the U.S. Capitol Complex.

The AOC staff provided the committee as much operating data as it could within the security limitations in force. In the two meetings in which the committee had the opportunity to review the information, interact with the staff, and have access to the facilities, it appeared that some information might not have been released to the committee for security reasons or might not have been available due to a lack of metering or instrumentation, or that it is simply not collected.

To the credit of the AOC staff, according to the AOC Web site the largest single contribution to the energy reduction efforts in the U.S. Capitol Complex is owing to improvements made at the CPP. This is typical of experiences on large institutional campuses in the United States where investments in district energy systems similar to that serving the U.S. Capitol Complex have provided efficiency improvements greater than those realized through improvements in the buildings on the campuses that are served. However, recent and proposed legislation coupled with activities such as the “Green the Capitol Initiative” (Beard, 2007) now require further attention to energy efficiency and reduction of greenhouse gas emissions.

Consulting Services

The committee was impressed with the number of options considered for the CPP and the routing of the distribution system in the 70% Report. The consulting teams demonstrated considerable knowledge and experience in the types of systems that exist to serve the U.S. Capitol Complex and the current and viable technologies for the energy infrastructures of the future.

The AOC staff directed the consultants to evaluate the potential impact of pending greenhouse gas (GHG) emissions regulations on the cost-benefit analysis of the options. The committee believes it is highly likely that GHG emissions legislation/regulation will be enacted within the life of the proposed energy infrastructure replacements; therefore this analysis is very important and probably has helped to shift the project requirements in a direction compatible with GHG regulations. In particular, it has become clear that using biomass or fuel cells as options to replace the CPP are not viable options *for the near term* even when the potential impact of GHG legislation is considered. In addition, in response to a request by the committee, a thorough CO_2 accounting was added to the 70% Report.

In the 70% Report, consideration has been given to viable energy distribution tunnel rehabilitation and steam and chilled water line routing options, as well as options for multiple central plants and stand-alone equipment located closer to the buildings being served. Multiple paths for the distribution systems were developed and analyzed, as were the possible reuse and the replacement of the existing tunnels. For replacement options, new tunnels, direct buried piping, and covered trenches have been thoroughly evaluated.

Consultants’ Report

The AOC specifically requested that the committee act as a second-level reality check against fatal flaws in the AOC methodology or strategic development. Within the parameters of the 70% Report, the committee did not find any fatal flaws in the analyses presented.

SHORTCOMINGS IDENTIFIED BY THE COMMITTEE

This section describes the shortcomings identified by the committee in the presentations at the workshop and in the 70% Report. The section that follows discusses the actions that the committee recommends be taken as the *Strategic Long Term Energy Plan* is carried from 70% to 100 percent completion, to overcome some of the identified shortcomings. Other shortcomings described in this section are undoubtedly beyond the scope of this activity. They can be addressed only as part of the broader set of analyses recommended by the committee, as presented in Chapter 3.

The identified shortcomings are as follows:

1. Lack of a clear statement of assessment criteria for the alternatives presented;
2. Lack of a holistic systems approach;
3. Acceptance of all current constraints as immutable;
4. Acceptance of all current relationships as permanently binding; and
5. Demand projections not supported by firm data and not reflective of applicable mandates for energy consumption reduction.

Lack of a Clear Statement of Assessment Criteria

The 70% Report culminates with a number of options for the CPP, each characterized by assessment criteria—such as cost, security, or environmental impact—and the corresponding index values. The committee assumes that there are similar capsule characterizations of the distribution system alternatives (the limited time available to examine the sensitive material did not allow for ascertaining this fact).

The committee could not find a clear statement in the 70% Report describing which criteria will be considered pertinent for assessing or ranking the proposed options for the CPP and the distribution network. Nor did the 70% Report present the full set of indices that will be used to assess the pertinent criteria. In principle, several sets of assessment criteria and their indices may be involved for the (a) consultants' recommendations for ranking the options; (b) AOC's internal evaluation and ranking of the consultants' recommendations; and (c) evaluation and ultimate decision making by the funding entities. These assessment criteria are especially significant given the high probability that criteria for very high (up to 100 percent) reliability or existing constraints on the CPP's operations will dominate, as discussed below.

Lack of a Holistic Systems Approach

The 70% Report immediately proceeds to the compilation of assumptions and background information concerning the CPP and the distribution system. It does not present an overarching holistic systems approach to the problem at hand.

The committee is not aware of the contractual relationship between the AOC and its consultants, and therefore does not know whether the elements listed below ought to be part of the consultants' report or ought to be generated by the AOC itself. In any case, a holistic system approach would encompass, among possible others, the following elements:

- A mission statement—a description of the AOC's mission with respect to providing heating, cooling and, potentially, electricity to the U.S. Capitol Complex, and its role in balancing priorities among the many possible performance criteria for the CPP;
- A vision statement—how the AOC intends to meet its intended mission;
- A clear statement of criteria and priorities that are to be satisfied, such as reliability and security, providing utilities services to new buildings, increased energy efficiency, avoidance of obsolescence, satisfaction of regulatory requirements, reduction of environmental impacts, contribution to the Green the Capitol Initiative, and reduction of greenhouse gas emissions;
- A system optimization methodology, formal or informal, for resolving potentially conflicting criteria in the selection of the CPP and distribution system option;

- A global reliability target—a clear statement of the level of service for reliability that the AOC intends to meet;
- A prioritization scheme of customers—definition of a process that the AOC would use to assign priority of service to the various jurisdictions it serves in the event of various types of emergencies wherein steam and/or chilled water outages would occur;
- An explicitly stated planning horizon for the CPP and distribution system solutions to be implemented—for example, a plant and distribution system that will handle at least 30 years of service and tunnels that can accommodate 100 years of service;
- A recommended approach for the phasing of capital outlays for both the CPP and the distribution system to meet the timing of increasing demands and to decrease net present costs;
- A justification of the need for a diversity of fuel types so as to maintain or increase CPP reliability and security;
- A clear statement of need for addressing major CPP equipment redundancies and multiple utility service connections for facilities;
- An approach that will allow the systems to be adapted to accommodate future changes in the operating environment (e.g., new greenhouse gas emissions legislation) and the development of new technologies; and
- An approach to the possibility of enclosing additional space now in both the CPP and the distribution system tunnels to accommodate additional equipment or utility lines in the future and avoid future costs.

Acceptance of Current Constraints as Immutable

The committee's evaluation of the 70% Report led it to infer that the report is based on the assumption that all current constraints concerning the project are immutably fixed, as opposed to being amenable to review, negotiation, and modification that may result in improved solutions. Some of the constraints listed below may indeed be immutable, as for example the insistence on well-proven, mature technologies in view of the criticality of providing reliable service to the U.S. Capitol Complex. Nonetheless, any such constraints should be explicitly stated. This would allow the AOC and others to periodically revisit the constraints and assess possible changes in the extent and implications of each constraint.

The constraints that appear so bounded include:

- *Current rights-of-way and alignments of the Metro subway system, railroad, gas, water, storm drainage, and sewer lines.* The 70% Report does not consider any option to realign some of these lines in order to improve the long-term efficiency or redundancy of the CPP distribution system alignments.
- *Use of or connection to other nearby federally owned district energy systems.* The General Services Administration (GSA) and the U.S. Navy operate district energy systems in proximity to the U.S. Capitol Complex. The report does not consider options that would use or connect to these systems or the possible costs and benefits of doing so.
- *Current interpretation of the agreement negotiated with the Office of Compliance concerning the distances between points of egress to facilitate worker safety in the distribution tunnels.* Because the report treats this agreement as immutable, it does not fully consider the possibility of new or substantially modified tunnel configurations (particularly larger-diameter, deep-bore tunnels) that would offer

increased worker comfort and safer evacuation routes. Egress points in deep-bore tunnels may be placed farther apart than currently agreed to and would require renegotiating the Office of Compliance agreement in accordance with relevant Occupational Safety and Health Administration (OSHA), Mine Safety and Health Administration (MSHA), and National Fire Protection Association (NFPA) regulations.

- *Current interaction with the District of Columbia government and the communities surrounding the tunnels and the CPP concerning access, noise limits, construction restrictions in extent and duration, and other factors of mutual concern.* Relaxation of some of the existing regulations or agreements could make additional alignments feasible or permit alternative construction and tunneling methods or logistics to be considered.
- *Use of a design-bid-build method for project delivery*. The report does not consider alternate methods for the procurement of the CPP and distribution system components, such as outsourcing or variants of design-build-operate-maintain contracts.
- *Current location of the CPP*. The report does not consider alternate outlier locations for the CPP.
- *Current insistence on fully "warrantable" technologies for consideration and the required high level of technology demonstration prior to consideration for adoption.* The report does not consider the future use of potentially beneficial renewable technologies (e.g., solar) except for biomass, once they are more fully developed and could be available to serve the peak load.
- *The apparent current focus on security and very high (up to 100 percent) reliability of services.* The report gives relatively little consideration to other performance criteria for the CPP or of alternative configurations of the tunnel system to address issues of redundancy.

Acceptance of All Current Relationships as Permanently Binding

The committee does not know whether the elements listed below ought to be part of the consultants' final Strategic Long Term Energy Plan or ought to be generated by the AOC itself. The report appears to take all current relationships within the AOC, other than the CPP and the 17 jurisdictions served by the CPP that constitute the larger Capitol community, as permanently binding.

An alternate approach favored by the committee is to view the current project and the current emphasis on energy efficiency and reduction of greenhouse gas emissions, as well as cost constraints, as an opportunity to explore fully the potential effect of modified or redefined relationships on elements such as:

- Increased coordination with the participants listed in the U.S. Capitol Complex Master Plan Sustainability Framework Plan on the implementation of the plan and other current and potential future statutory mandates for energy consumption reduction;
- Increased liaison with the managers of building retrofit projects to assess alternatives designed to decrease energy use or, at least, lessen increases required by new regulations or planned uses of the space;
- Collaboration with other U.S. Capitol Complex entities in developing a climate action plan for the complex that summarizes current levels of GHG and hazardous air

pollutant emissions, describes the results of analyses, defines chosen mitigation strategies, and reports the results of implementation;

- Exploration of shutting down portions of the power plant on a rotating basis during the nonheating months, within reason and within mechanical integrity and safety guidelines, to allow for maintenance and reduce emissions during the critical summer ozone season. Such an approach might also provide for extending the service life of steam generation equipment, an improved energy balance, reduced ozone emissions, opportunities for conducting preventive maintenance during down times, and improved worker safety and comfort; and
- Improved coordination and closer relationships among all divisions of the AOC and with other entities responsible for building maintenance on issues such as:

  - expedited implementation of energy metering programs;
  - possible load reductions as a result of compliance of the U.S. Capitol Complex buildings with further energy reduction targets;
  - possible heat recovery in buildings;
  - consideration of chilled water storage and chilling of the water during off-peak hours to improve the overall energy balance and system reliability;
  - possible reductions in winter demand for chilled water;
  - potential alternate means of humidification;
  - potential alternate supplies of hot water;
  - efforts to increase the condensate return rate;
  - possible beneficial use of grey or reclaimed water;
  - establishing energy audits and measuring performance against conservation/efficiency goals; and
  - potentially establishing awards for annual energy conservation/efficiency and cost-effectiveness.

Demand Projection Analysis

A large part of Division 3 of the 70% Report deals with current and future energy demands of the U.S. Capitol Complex served by the CPP and the distribution system. The committee notes that:

- Because metering of actual steam and chilled water is being upgraded, current individual building demands are calculated on a percentage of square foot basis;
- Projected future demands will require further evaluation considering all the known requirements on the system and, specifically, the statutory mandates for energy consumption reduction;
- A 20 percent increase is required for future steam and chilled water demands for renovated space based on current building codes and increased air changes above current standards; and
- Projected global climate change impacts are not considered in the report.[1]

[1] New reports on the possible impacts of global climate change are being issued. For example a recent report by the U.S. Global Change Research Program and the National Oceanic and Atmospheric Administration projects that the Washington, D.C., region's average annual temperatures will rise between 4.5 degrees and 9 degrees by the end of this century (U.S. Global Change, 2009). Such changes will have an impact on heating and cooling requirements.

The committee lacks the expertise to further assess these forecasts but recommends that the AOC further investigate the projected increases.

ADDITIONAL WORK RECOMMENDED

The 70% Report presents and evaluates 10 different options for the CPP, the decentralization of certain functions of the CPP, and options for the tunnel distribution system. The committee recommends that additional work be conducted in the strategic areas described below to bring the 70% Report to 100 percent completion as the *Strategic Long-Term Energy Plan* and to support and justify the consultants' recommendations for the selected option(s), as follows:

1. Articulate the methodology used for evaluating and selecting the option(s);
2. Develop additional indices to be used to evaluate the options;
3. Integrate construction phasing with the energy demand planning horizons;
4. Conduct more comprehensive environmental evaluations of the options;
5. Evaluate the likelihood that the options would meet regulatory requirements;
6. Perform sensitivity analyses for different CO_2 allowances and fuel availabilities and prices, given the uncertainty in future greenhouse gas regulations and energy supplies/prices;
7. Evaluate distribution tunnel layouts; and
8. Summarize the results and rationale for the selected option(s).

Articulate Evaluation and Selection Methodology for Options

Division 3 of the 70% Report provides a summary of the assumptions and background information for the analysis of the various options. This information includes the current and future energy demands of the U.S. Capitol Complex; the fuel characteristics and current and future fuel costs for the CPP; utilities supplied by outside entities (electricity provided by PEPCO and water provided by the District of Columbia Water and Sewage Authority (WASA); the environmental framework for CO_2 and hazardous air pollutants; and the current status of the CPP. Division 4 presents the CPP options and Division 5 presents the distribution system options.

However, there is no discussion in the 70% Report of the methodology that will be used to evaluate and narrow down the option(s). In order to ensure that the AOC and its consultants are aligned in their methodology, and that the report audience understands the basis for the selection of the recommended option(s), the final report should articulate the methodology used to evaluate and select it (them). The methodology should also consider the differential cost impacts of the various options.

Develop Additional Evaluation Indices

The 70% Report appears to be using several different indices to rank options. These include:

- *Life-cycle costs*—including initial capital costs, present value of ongoing costs, and total present value;

- *Environmental impacts*—limited to greenhouse gas emissions (local and regional impacts) and hazardous air pollutant emissions;
- *Energy rating*—the efficiency of conversion of energy input (fuels) to energy output calculated as energy output/energy input; and
- *Security impact*—related to the capability of the CPP to continue to operate and provide utilities if externally supplied electricity and water are interrupted.

Although these indices are determined for each option, the 70% Report is silent on the acceptable level(s) for these indices and on how these indices were selected. In conjunction with the proposed articulation of the methodology for evaluating and selecting option(s), the committee recommends that the consultants evaluate the appropriateness of the indices identified in the 70% Report, determine whether these indices are sufficient and whether other indices may be appropriate, and determine the acceptable level(s) for these indices. For example, additional indices could include construction lead time; extent and duration of disruptions to the Complex and the surrounding communities; sensitivity to risk of construction delays and disruptions; potential for adoption of future technologies; and fit with load reduction programs for existing and new buildings.

In addition, the committee recommends that the report further refine and define its evaluation of the security impacts of outside utility disruptions (i.e., electricity and water) and develop a realistic index of system reliability of the options commensurate with the indices chosen.

Integrate Construction Phasing with the Energy Demand Planning Horizons

The committee applauds the consultants for providing a breakdown of future energy demands in the 70% Report according to three planning horizons:

- Near-term: 0 to 5 years;
- Intermediate-term: 6 to 10 years; and
- Maximum growth: 11 to 25 years.

The 70% Report provides a breakdown of future steam, chilled water, electricity, and domestic water consumption. In addition, the 70% Report identifies when future demands for steam and chilled water will exceed current CPP capacity (including current planned modifications). These planning horizons provide an additional level of detail to the report's analysis of CPP expansion requirements.

However, the energy demand planning horizons do not appear to be integrated with the planning horizons for the CPP and distribution system options. For instance, the report indicates that a significant portion of the future growth in demand will be located away from the CPP on the north end of the U.S. Capitol Complex. The report does not account for potential phasing of construction in its evaluation of the Non-CPP or Additional Plant Strategy Options (CPP Options P-1 to P-6). The committee recommends that the report integrate the energy demand planning horizons into the evaluation and selection of option(s) for both generation and distribution of steam and chilled water.

Conduct More Comprehensive Environmental Evaluations of the Options

The committee applauds the consultants and the AOC for augmenting the GHG and hazardous air pollutant emissions analysis of each option in the 70% Report,[2] as suggested during the committee's meeting in December 2008. The life-cycle cost analyses for the alternatives incorporate quantified CO_2 allowance costs for greenhouse gas emissions.[3] This will provide an important basis for more detailed climate action planning for the final and selected options.

However, the quantified hazardous air pollutant emissions do not appear to be used in the evaluation of options. The committee recommends that these results be used to quantify potential incremental risk impacts on the surrounding community. Further, a more comprehensive analysis of the potential environmental impacts of the options should be discussed in the final report. For instance, a number of options contemplate using an alternate fuel mixture such as 100 percent natural gas versus the current fuel mix that includes coal. The 100 percent natural gas alternative could have positive environmental benefits (some quantifiable) from eliminating coal ash disposal, eliminating coal transport emissions, and reducing hazardous air pollutant impacts on the surrounding community. However, using only one type of fuel would make the CPP more vulnerable to disruptions in supply or fluctuations in the price of that fuel. Other options (e.g., the use of biofuels) will have different environmental impacts and may provide additional flexibility in the event of price fluctuations and provide additional security in the face of supply disruptions.

Evaluate Likelihood That Options Would Meet Regulatory Requirements

Based on the results of a more comprehensive environmental evaluation, the AOC and its consultants should determine the "permittability" of the options, the potential lead time required for permitting, and the potential hurdles to permitting, including potential community opposition to noise, traffic, visual, direct environmental, and other impacts from each option. Options such as waste-to-energy or coal gasification would likely result in significant public opposition and possibly result in a permitting timeline extending several years, with less than 100 percent certainty that permits would ever be issued. In addition, warmer temperatures caused by global climate change could accelerate ozone production.

In addition, the report should discuss how each option could be adapted to meet more stringent air quality standards, such as may be imposed if the District of Columbia fails to attain ambient air quality standards within a specified timetable. Such issues could impact the selection of viable option(s) and should be clearly identified in the report.

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[2] The calculation of carbon emissions for each option accounted for local emissions from fuel combustion at the CPP; regional emissions from the purchase of electricity by the CPP and the AOC; and mitigating impacts of purchase of Renewable Energy Certificates (RECs). CO_2 emissions from fuels combustion were treated as positive emissions at both the local and the regional levels, with the exception of the option using biomass, which was "zeroed out." Emissions factors for each fuel were obtained from the Climate Registry's General Reporting Protocol of May 2008. The calculation of hazardous air pollutant (HAP) emissions for each option included local emissions based on fuels combusted by the CPP and regional emissions based on purchased electricity. Emissions from CPP fuel combustion were estimated using generally accepted emissions factors, such as EPA's AP-42 compilation of emission factors.

[3] Three analyses were conducted to project CO_2 allowance and electricity prices: analyses by the American Council for Capital Formation/National Association of Manufacturers; the EPA; and the U.S. Department of Energy's Energy Information Administration. These analyses projected that carbon allowance prices in the United States could range between $15 and $98 per metric ton in 2020 and between $24 and $271 per metric ton in 2030. The cost impact of each CPP option was estimated in the report by conservatively assuming (1) that all combustion emissions (other than biomass combustion) will involve costs to purchase allowances equivalent to the quantity of CO_2 emissions; and (2) no deduction of baseline emissions.

Perform Sensitivity Analyses to Different CO_2 Allowances and Fuel Prices

The 70% Report does not provide the base assumptions for CO_2 allowances and future fuel prices. In addition, while the focus of proposed legislation has been on a cap-and-trade system, there has been discussion of a different structure such as a carbon tax. A carbon tax could have significantly different implications for power plants using conventional fossil-fuel-fired equipment and power plants designed around renewable fuels (e.g., biomass or solar) than would a cap-and-trade system for greenhouse gas credits. Given the uncertainty in future greenhouse gas regulations and the potential variability in future fuel prices (either as a result of the inherent variability in fuel prices or as the result of a carbon tax), the committee suggests that the life-cycle costs include an analysis of sensitivity to variations in CO_2 allowances and fuel prices. Because implementation of certain options will be phased in over time, the impacts of variations in CO_2 allowances and fuel prices may differ over the life of each option.

Evaluate Distribution Tunnel Layouts

The 70% Report discusses only one deep tunnel option for the utility distribution system. In order to provide an adequate basis for comparing options, it is suggested that a study be made of potential distribution tunnel layouts and available construction methods (e.g., microtunneling, horizontal directional drilling) to assess the best approaches for minimizing disruptions to the surface, traffic, and the community while optimizing the efficiency, phasing, and redundancy of the system, and improving the safety of the tunnel environment for workers conducting maintenance and repair activities. As noted above, such options may require renegotiating current agreements with the Office of Compliance regarding maximum distances between egress points.

Summarize the Results and Rationale for the Selected Option(s)

The final report should provide a concise summary of the results and rationale for the selected option(s). The methodology and indices (including the acceptable level(s) for these indices) used for evaluating and selecting the appropriate option(s) should be included.

3
Recommended Additional Analyses

Chapter 3 responds to the broader charge to the committee, asking it to "recommend how the Capitol Power Plant can be best positioned to meet the future strategic and energy efficiency requirements of the U. S. Capitol Complex." The committee recommends an additional set of analyses that could be performed to this end. The common theme of these analyses is to differentiate the unique aspects of the CPP project from typical district energy projects, and to seize the opportunity for setting an example for the nation in regard to energy reliability, efficiency, cost-effectiveness, and security and with respect to environmental stewardship.

The recommended additional analyses are as follows:

1. Reliability and risk assessments;
2. Comparative demand and supply projections;
3. Workforce demand evaluation;
4. Exploration of a wider range of technologies;
5. Benchmarking; and
6. Response to shortcomings identified.

RELIABILITY AND RISK ASSESSMENTS

One important area that has not received sufficient attention is the perceived ability of each option proposed in the 70% Report to continuously generate and deliver the required services. In order to provide a consistent comparative assessment of the proposed options it is necessary to conduct a comprehensive risk analysis of each one. The numerical analyses should provide quantitative reliability indices that respond to the actual factors that influence the ability of the CPP system to perform its required functions. This cannot be done using deterministic techniques. It requires the application of probability methods.

The current CPP system reliability philosophy appears to be based on the provision of redundant elements at the system and subsystem levels. Firm steam and refrigeration capacity are defined as the capacities remaining after the loss of the largest boiler or chiller, respectively. Although it is recognized that this methodology is commonly used for complex systems and does provide very high reliability of such systems, this is a deterministic approach that does not incorporate the *probability* of failure of a boiler or chiller. A similar situation exists at the CPP subsystem level and in the delivery aspect of the CPP system mandate, involving tunnels and alternate flow paths.

CPP Option 1 is an extension of the existing CPP using various fuel options. Reliability considerations are referred to in the 70% Report as security impacts and indicate only the ability to provide steam and chilled water under a PEPCO outage and the loss of water from the WASA. The report provides no indication of the likelihood of a PEPCO or WASA outage in the future, or details of past outages.

The 70% Report contains a summary of planned and unplanned outage times for the major components in the heating and refrigeration systems. This is useful information. The available capacities for each day in the heating and refrigeration systems were calculated by comparing the coincidental planned/unplanned outages of each major component in the two systems. The report states that the outage data were consolidated on a monthly basis and compared with the system peak load to determine the availability of the CPP to serve the monthly steam and chiller requirements of the U.S. Capitol Complex. The report notes that monthly availabilities greater than 100 percent indicate excess capacity. This is an interesting general analysis of the recent past performance of the existing plant. However, it does not provide a frame of reference or specific reliability indices that can be used in a comparative analysis of the present system and other options.

The word "availability" in common reliability engineering analysis is typically used to express the probability or percent of time that a component or system is in the operable state where it can perform its intended function. In the case of the steam and chiller systems in the CPP, the concepts of availability and unavailability can be extended to provide the probabilities of various output levels in the two systems resulting from subcomponent failures and other factors such as fuel, water, and electricity supply. The steam and chiller probability models can be combined with the relevant CPP demand models to produce responsive plant reliability indices. These indices can also be used to assess the reliability implications associated with increased or uncertain load demands and the reliability effects of decreased load demands due to building efficiency or technology improvements. The CPP models can also be combined with probabilistic delivery system models to produce AOC building reliability indices.

CPP Option 2 uses the concept of cogeneration to meet the electric, steam, and chiller requirements, while Option 3 involves the construction of a new conventional plant using different fuel mixtures. In each case, the ability to serve these functions can be examined using an approach similar to that applied to Option 1 and expressed by similar reliability indices.

Similar analyses can be conducted for Primary Options 4 through 10, if required. These options involve advanced technologies that may not have yet matured and been placed in commercial service. In these cases, there may be relatively little or no available reliability data. The basic methodology and resulting indices should, however, be common to all the analyzed options.

In summary, the committee recommends that a comprehensive risk analysis of the viable proposed options be performed before a commitment is made to any of them. This should include a clear statement of the governing reliability criteria and include numerical reliability indices that can be used to facilitate the decision-making process. The indices should express the ability of the CPP system to meet the future demands for electricity, heating, and refrigeration; account for the age of the primary and auxiliary equipment; and include the reliability of water, fuel, and grid-supplied electricity. The analyses should include the ability of the CPP to meet the electricity, heating, and refrigeration requirements and the ability of the tunnel configuration to deliver these requirements, including a differential analysis of looped tunnels versus pipe loops in single-tunnel configurations. An evaluation of the risk of cascading failures among steam, chilled water, and other utility lines within the tunnels may also be appropriate. The basic methodology used in evaluating the reliability indices should also be amenable to incorporating renewable fuel alternatives such as solar thermal, solar photovoltaic, and wind power generation in future applications.

COMPARATIVE DEMAND AND SUPPLY PROJECTIONS

Congress and the AOC's other clients in the U.S. Capitol Complex need a strategic decision-making tool to aid them in planning and seeking funding for the upgrading of the CPP and the utility distribution system. As part of the holistic approach described in Chapter 2, such a tool needs to present demand and supply projections based on:

- The existing demand profile, including historic and forecasted levels of load growth;
- An upgraded energy efficiency/conservation effort demand profile (which would entail future modernization projects for the AOC); and
- An "optimum" demand profile, where Congress and the AOC could show leadership on the type of energy demand reduction "diet" they are striving for and that would go a long way toward underpinning the need for the selected CPP option.

WORKFORCE DEMAND EVALUATION

The operational changes in the CPP and the distribution system that would be produced by the various options would have considerably different impacts on the AOC workforce in terms of training and staffing. For instance, the labor costs and skills to operate and maintain gas-fired boilers, co-generation plants, and coal-fired plants vary significantly. This crucial issue appears not to have been addressed in the 70% Report. As the range of options is narrowed down, differential scenarios for labor costs, training, and staffing for each option should be projected.

EXPLORATION OF A WIDER RANGE OF TECHNOLOGIES

The 70% Report considers a range of technologies deemed "warrantable" at the present time. Considering that the report addresses a planning horizon up to 25 years (and that public funding generally proceeds at a very slow rate), a long-term study of a wider range of technologies *that may become warrantable* should be undertaken. This will allow the consideration of successful technologies as the Strategic Long Term Energy Plan is periodically brought up to date. These technologies include, but are not limited to:

- Novel fuel mix strategies;
- Feasible alternative or renewable fuel options;
- Heat recovery in the supply and use of energy;
- Improved heat balance through the use of auxiliary drives;
- Limiting supply of steam in the summer and satisfying small heating loads through other methods;
- Use of superheated steam rather than saturated steam;
- Chilled-water storage systems;
- Metering technologies for all major plant equipment and energy destinations;
- Fully integrated digital controls;
- Real-time modeling of plant operations, chilled water and steam hydraulics, and environmental effects;
- State-of-the-art tunnel construction methods;
- Geothermal heating and cooling; and
- Use of solar panels on building roofs and the grounds of the U.S. Capitol Complex.

Such a study may evolve into a technology-monitoring program, however informal, for anticipating technologies that may become available in an even longer time span, say 50 to 100 years.

BENCHMARKING

The committee recommends that the AOC develop a plan for measuring the performance of the CPP complex, using benchmarks for efficiency of operations, environmental compliance achievements, and other measures. A sample benchmarking form is shown in Appendix D. If feasible, the benchmarking of the AOC facilities should be augmented by collecting comparable data from other district energy systems, including those of the General Services Administration and the Washington Navy Yard, and collecting and implementing best-in-class practices.

RESPONSE TO SHORTCOMINGS IDENTIFIED

As a general catchall category, the committee recommends that the AOC review the shortcomings identified in Chapter 2 that have not been explicitly addressed as recommendations for additional work, and develop an action plan to address those shortcomings it considers material.

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APPENDIXES

Appendix A
Biosketches of the Committee Members

Steven J. Fenves, *Chair,* is University Professor Emeritus of Civil and Environmental Engineering at Carnegie Mellon University. He received his degrees in civil engineering from the University of Illinois. He has taught at the University of Illinois, Carnegie Mellon University, MIT, National University of Mexico, Cornell University, and Stanford University. Dr. Fenves' research and teaching have dealt with computer-aided engineering, encompassing design data modeling, design standards, design environments, engineering databases, knowledge-based systems, and structural engineering analysis tools. He is the author of six books and more than 400 articles and reports. As Guest Researcher in the Manufacturing Engineering Laboratory at NIST between 1999 and 2008, Dr. Fenves led projects on product modeling, design-analysis integration, and environments for advanced engineering and healthcare delivery. Dr. Fenves continues to work part-time for NIST as a contractor. Dr. Fenves is a member of the National Academy of Engineering and an Honorary Member of the American Society of Civil Engineers. Among his awards are the Huber Prize and the Moisseiff and Winter Awards from ASCE, the Engineering College Alumni Honor Award and the Civil Engineering Department Distinguished Alumnus Award from the University of Illinois, the Teare Award and Doherty Prize from Carnegie Mellon University, and a Lifetime Achievement Award from the American Institute of Steel Construction, Inc.

Carmine Battafarano is the vice president, Technical Services, for Burns and Roe Services Corporation. Burns and Roe is a privately held, comprehensive engineering, procurement, construction, operations, and maintenance organization with specialized expertise in technically complex facilities in power, industrial, infrastructure, and government services industry. Mr. Battafarano is responsible for the group's optimization (including energy management and utility master planning) and modernization services. He is a certified energy manager, certified sustainable development professional, and licensed chief engineer and has more than 15 years' experience with operations and maintenance of utility infrastructure systems. His experience includes serving as plant manager of a district energy plant (thermal, chilled water, and electrical), serving as a project manager for numerous central utility plant operations, and serving as an asset manager for a national energy company. Prior to joining Burns and Roe Services Corporation he was employed as an environmental attorney with the law firm of Norris McLaughlin and Marcus. Mr. Battafarano is a member of the Virginia State Advisory Board on Air Quality, is a member of the Energy Bar Association, and is active with numerous professional organizations and with environmental and energy regulatory issues. He has served as a moderator for the IDEA conference related to master planning and LEED design; presented at New Jersey's Higher Education Partnership for Sustainability discussing Campus Sustainability and O&M; presented on LEED guidelines; and presented on non-electric generating unit mercury emissions at the Virginia Annual Air Quality conference. Mr. Battafarano holds a BS in engineering from the U.S. Merchant Marine Academy and a JD from New York University Law School.

Roy Billinton is an emeritus professor, Department of Electrical and Computer Engineering, University of Saskatchewan. He was elected to the National Academy of Engineering in 2007 for contributions to teaching, research, and application of reliability engineering in electric power generation, transmission, and distribution systems. Dr. Billinton is actively involved in research dealing with engineering system reliability evaluation with a particular emphasis on electric power systems. The concepts and techniques developed by the Reliability Research Group have been applied in a wide range of power system applications. These include work in generation capacity planning, composite generation and transmission system evaluation, and distribution system analysis. A present focus of the research is to combine power system security considerations with the more conventional adequacy assessment techniques to create an overall framework for power system reliability assessment. The Reliability Research Group has pioneered the development of reliability worth/reliability cost concepts for power system optimization and decision making. Dr. Billinton has authored or co-authored eight books on reliability evaluation and more than 775 papers on power system reliability evaluation, economic system operation, and power system analysis. He holds BSc, MSc, PhD and DSc degrees in electrical engineering from the Universities of Saskatchewan and Manitoba.

Brenda Myers Bohlke is the president of Myers Bohlke Enterprise, LLC, a consulting firm, and the chair of the Underground Construction Association of the Society for Mining, Metallurgy, and Exploration. She was formerly the vice president and corporate manager for Research, Development & Innovation at Parsons Brinckerhoff, Inc. Dr. Myers Bohlke has more than 20 years of experience in support of a variety of underground and civil design projects and has previously served on National Research Council committees. Her background includes professional and academic training in traditional geology, rock mechanics, soil mechanics, and the design and construction of underground structures, including mechanized tunneling. In 1988 Dr. Myers Bohlke was selected as a Congressional Fellow by the National Society of Professional Engineers. She served as science and technology advisor to Senator Daniel P. Moynihan (D-NY) for public works issues and as a staff member on the Senate Committee on Environment and Public Works. She advised on issues surrounding infrastructure, environment, and high-speed ground transportation. As Senator Moynihan's advisor, her responsibilities also included evaluation of research programs for funding recommendations, staffing on technical issues, infrastructure funding, cleanup of hazardous waste, environmental and coastal zone management issues, and waste disposal. Dr. Myers Bohlke earned a BS in geology from the University of Maryland, an MS in marine geology/geotechnology from the University of Miami, and a master's degree in engineering science and a PhD in geotechnical and underground design from the University of California.

Raymond E. DuBose is the director for Energy Services at the University of North Carolina at Chapel Hill, where he has worked for the past 33 years. As the director for Energy Services, he oversees a department of 150 employees, with responsibility for long-range planning, capital program management, operation, maintenance, and cost allocation for all campus utilities and central energy plants. Energy Services is a receipt-supported auxiliary on the university campus with receipts of $100 million per year. Mr. DuBose is also leading the university's energy planning for its new 900-plus-acre Carolina North campus, where the university is seeking to use 100 percent alternative energy sources in its energy production. Mr. DuBose has been an active member of the International District Energy Association (IDEA) for the past 22 years. IDEA's core mission is to support the growth and use of district energy as a means to conserve fuel and increase energy efficiency to improve the global environment. He has held many positions within the IDEA and has served on the board of directors. In 2003, he received the Norm Taylor Award, IDEA's highest recognition of service to the district energy industry. In 2007, he received a 20/20 Vision award for visionary leadership and continuous commitment to the advancement of the association. Mr. DuBose is an active member of the UNC-Chapel Hill Vice Chancellor's Sustainability Advisory Committee and the Higher Education Committee of the American

Council of Renewable Energy. He holds membership in the Professional Engineers of North Carolina. Mr. DuBose received a bachelor of science degree in mechanical engineering from the University of Tennessee, Knoxville, and he is a registered professional engineer in North Carolina.

Peter H. Emmons is the CEO and co-founder of Structural Preservation Systems, a concrete and structural repair firm with more than 2000 employees located in 29 offices in the United States and the United Kingdom, and annual revenues of $430 million. Mr. Emmons initiated and developed the first industry guideline for the preparation of concrete surfaces to improve the service life of repairs to concrete. He has also developed the Comprehensus Knowledge Management System for concrete-related operations and maintenance, and has led an effort to create a worldwide concrete repair manual. Mr. Emmons is a founding member and past president of the International Concrete Repair Institute, and has served as a member of the American Concrete Institute (ACI) board of direction and as a past chair of the Accelerating Technology Acceptance program of ACI. He is the author of several books and the recipient of numerous awards. He holds a BS in civil engineering from the University of Maryland.

Juan M. Ontiveros is the executive director of utilities and energy management at the University of Texas-Austin. In this position he is responsible for a budget of $70 million and 180 employees and oversight of a large district energy system composed of a combined heat and power plant, steam plant, chilling stations, and underground utilities. Mr. Ontiveros has more than 25 years' experience in power plant modernization, utility master planning, fuel procurement, chilled-water optimization, and system controls. He is currently the first vice chair of the executive board of directors of the International District Energy Association. Mr. Ontiveros has also served on the Texas Higher Education Coordinating Board, the Texas Association of Physical Plant Administrators of Universities and Colleges, the Texas Comptrollers Energy Efficiency Task Force, and as a member of the Information and Telecommunications Advisory Committee for the University of Texas at El Paso. He earned BS and MS degrees in mechanical engineering from the University of Texas-El Paso and is a registered professional engineer in Texas.

Alan S. Shimada is a principal at ENVIRON International Corporation. He has nearly 30 years of diversified engineering experience in industry, government, and consulting, including 10 years with Exxon and DuPont, several years with the U.S. Environmental Protection Agency, and 16 years in environmental consulting. He is particularly experienced in addressing air compliance issues in complex facilities such as power plants, chemical plants, petroleum refineries, and pharmaceutical facilities. Mr. Shimada has extensive technical expertise in air quality compliance; air quality permitting and emissions quantification and control evaluation; compliance with hazardous air pollutant requirements; and emissions trading. He has provided oversight of state-issued prevention-of-significant-deterioration permits for several co-generation plants and has conducted a number of power plant environmental due diligence reviews, including power plants fired by coal, gas, oil, and renewable fuels. He has assisted facilities in documenting and generating emissions credits to comply with and/or participate in federal and state emissions trading programs such as the EPA Acid Rain, Ozone Transport Region NO_x Budget, and New Jersey Open Market Emissions Trading Regulations. Mr. Shimada holds a BS in chemical engineering from the University of Utah and an MBA from Columbia University.

C. B. (Bob) Tatum is the Obayashi Professor of Engineering at Stanford University. He joined the Stanford construction faculty in 1983 after nearly 15 years' experience in heavy industrial and military construction. He served as coordinator of the construction program from 1996 to 1999 and became department chair in 1999. He is a mechanical engineering graduate of Virginia Polytechnic Institute (BSME 1966) and the University of Michigan (MSE 1970), and earned a master's of business administration from New York University. Professor Tatum has taught courses on construction engineering and mechanical and electrical systems for buildings in Stanford's graduate construction program and undergraduate CE curriculum, high-tech and industrial construction, concrete construction, management of technology, case studies in managing construction projects, cost engineering, and materials management. His industry experience included responsibility as a mechanical engineer, construction engineer, resident engineer, and construction superintendent/area manager with Ebasco Services Incorporated (1970-1981) on two large power plant projects. He is a registered professional engineer in Colorado and Washington. In 1986 he received the Presidential Young Investigator Award from the National Science Foundation and in 1988 he received ASCE's Construction Management Award. He was elected to the National Academy of Construction in 2002.

Appendix B
Biosketches of Participants Invited to Capitol Power Plant Workshop

Get W. Moy is the associate vice president and senior program director for federal projects for DMJM H&N, a global design, management, and technical services firm. Prior to joining DMJM H&N, Dr. Moy served as an engineer for various sectors of the federal government, including the Naval Facilities Engineering Command and the Department of Defense. As director of utilities and energy, Office of the Deputy Under Secretary of Defense (Installations and Environment), he was responsible for DOD's energy program, offering insight on issues such as security of the utility infrastructure, the role of distributed generation and renewable energy, fluctuations in energy prices, energy and water resource management, utility acquisition, and utilities privatization. As the director of installations requirements and management at the DOD, he was responsible for the administration and direction of installations worldwide. Dr. Moy has managed complex programs for the federal government, including projects with stringent energy and environmental mandates. His expertise includes program and construction management, and sustainable design and management.

Christopher T. Payne is a scientist at the Lawrence Berkeley National Laboratory who is currently involved with the Green the Capitol Initiative. His research interests and expertise include energy consumption decision making, energy consumption and comprehension in the small business sector, qualitative analysis of energy consumption behavior, common conceptions of energy use and environmental issues, environmental identity in the work environment, organizational culture and its effect on environmental values, global climate change, energy conservation, and environmental protection.

Rush D. Robinett III is senior manager of the Energy and Infrastructure Future Group at Sandia National Laboratories. His multidisciplinary team of scientists and engineers develops and implements new concepts in renewable and clean energy, transitional fuels, advanced power electronics and energy storage, and controls and communications for the future electric generation and distribution system. In January 2008 he was a team member of the Intergovernmental Panel on Climate Change scoping committee on Renewable Energy Sources and Climate Change.

David A. Skiven is a facilities management consultant and frequent advisor to federal agencies, including the U.S. Navy and the U.S. Air Force. He is also currently serving as co-director of the Engineering Society of Detroit Institute, a nonprofit organization dedicated to improving Michigan’s economy. Mr. Skiven retired as the executive director of the General Motors Corporation Worldwide Facilities Group in 2007. The Worldwide Facilities Group was responsible for providing facilities management, utilities, construction, and environmental segments, allowing General Motors’ clients to focus on their core business, resulting in structural cost savings and improved utilization of assets. In 42 years at GM, Mr. Skiven worked in various engineering and plant operations, including manager of Facilities and Future Programs-Manufacturing Engineering for the Saturn Corporation, and director of Plant Environment and the Environmental Energy Staff before being appointed executive director of the Worldwide

Facilities Group in 1993. He has served as a member of the NRC's Board on Infrastructure and the Constructed Environment, on the board of directors of BioReaction, Inc., and on the board of the Engineering Society of Detroit. Mr. Skiven has a BS degree in mechanical engineering from General Motors Institute (GMI) and an MS degree from Wayne State University. He is also a registered Professional Engineer.

Raymond L. Sterling is the former director of the Trenchless Technology Center at Louisiana Tech University. The primary goal of TTC is to provide international leadership in trenchless technology activities that enhance construction productivity, environmental improvement, and rehabilitation of the infrastructure. The specific objectives of the center are to conduct basic and applied research for industry and government agencies; assist industries in developing, marketing, and manufacturing new products; promote technology transfer within the industry; establish and disseminate standard guidelines and specifications; monitor proposed regulations that impact the industry; develop contractor, designer, and inspector certification programs; and provide liaison with related trade and professional organizations.

Appendix C
Committee Meetings and Agendas

THURSDAY, DECEMBER 4, 2008

8:30 am-11:00 am	Administrative Items for Committee and NRC Staff only
11:15 am-12:15 pm	Welcome and Introductions of Committee and AOC Staff and Consultants Background Briefing about the Capitol Power Plant Project and Strategic Plan Mark Weiss and Chris Potter, AOC staff
1:00-4:00 pm	Consultant Presentations of Alternatives for Capitol Power Plant and Discussions with Committee
4:15 pm	Summary of Findings and Recommendations of Government Accountability Office Regarding the Capitol Power Plant and Utility Tunnels Terrell G. Dorn, Director, Physical Infrastructure Issues, Government Accountability Office
5:00 pm	Committee's Preliminary Discussion of Workshop Format • Discussion of Draft Agenda • Begin Identifying Potential Participants • Agree on Process for Inviting Participants
6:30 pm	Committee Working Dinner

FRIDAY, DECEMBER 5, 2008

8:30-12:00 pm	Site Survey/Tour of Capitol Power Plant
1:00-2:30 pm	Consultant Presentations on Tunnel Alternatives and Discussion with Committee
2:45 pm	Determine Date for Workshop Continued Discussion of Workshop Format

	Schedule Conference Call for Committee in Advance of the Workshop to Finalize Details
3:15 pm	Final Comments from Chair and Committee Members
3:30 pm	Adjourn

THURSDAY, MARCH 12, 2009 WORKSHOP

8:30-9:00 am	Welcome, Introductions, Workshop Objectives, and Ground Rules Steven Fenves, Committee chair, and NRC staff
9:00-10:30 am	Consultant Presentations o Energy Needs and Predictions of Future Requirements o Strategies for Serving Energy Needs o Utility Distribution System Options
10:45-11:15 am	Discussion: Issues and Options Juan Ontiveros and Ray DuBose, Committee members
11:15-12:00 pm	Discussion: Energy Needs and Predictions of Future Requirements Juan Ontiveros, Committee member, Moderator
1:00-1:45 pm	Discussion: Distribution Options and Discussion: Strategies for Serving Energy Needs Brenda Bohlke, Committee member, Moderator
1:45-2:30 pm	Discussion: Utility Distribution Systems Carmine Battafarano, Committee member, Moderator
2:45-3:30 pm	Discussion: Areas That Seem Well Developed or Warrant Further Investigation Bob Tatum, Committee member, Moderator
3:30-4:15 pm	Discussion: Evaluation Criteria for Consultant Proposal Roy Billinton, Committee member, Moderator
4:15-4:45 pm	Discussion: Summary of Workshop Steven Fenves, Committee chair
4:45-5:00 pm	Public Comment
6:30 pm	Committee Working Dinner

Appendix D
Sample Format for Benchmarking Data

GSF Served			
Annual Electrical Used (KWh)			
Fuel Type Used	**Coal**	**Natural Gas**	**Fuel Oil**
Annual Fuel Amount (Tons, MMBTU, gallons, KWh)			
Campus Peak Load (MW)			
Equipment Type	**Combustion Turbine**	**Steam Turbine**	**Recip Engine**
Equipment Rated Capacity (MW)			
Total Annual Steam Production (lbs/hr)			
In-Plant Steam Pressure/Temp (psi, degrees F)			
Distribution Steam Pressure/Temp (psi, degrees F)			
Fuel Type Used	**Coal**	**Natural Gas**	**Fuel Oil**
Annual Fuel Amount (Tons, MMBTU, gallons, KWh)			
Peak Load (lbs/hr)			
Equipment Type	**Boiler Fluidized Bed**	**Boiler Stoker**	**Boiler (Natural Gas)**
Total Rated Capacity			
Chilled Water (ton-hr)			
Fuel Used	**Purchased Electricity**	**Self Generated Electricity**	**Steam**
Annual Fuel Amount (KWh, KWh, lbs/hr)			
Peak Load (tons)			
Equipment Type	**Electric Chiller**	**Steam Turbine Driven Chiller**	**Absorption**
Equipment Rated Capacity (tons)			
Average Annual Steam Efficiency (%)		**Total Steam Out/Total Fuel Used[1]**	
Average Annual Heat Rate (BTU/KWh)			
Average Annual Chilled Water COP			
Average Annual System Efficiency %		**(Total Energy Delivered to Campus)[1]/(Total Fuel Used)[1]**	
Fuel Cost			
Average Annual Coal Cost ($/ton)			
Annual Average Natural Gas Cost ($/MMBTU)			
Annual Average Generated Electrical Rate ($/KWh)			
Annual Average Purchased Electrical Rate ($/KWh)			
Customer System Reliability (Last Year in %)		**((24x365)-Total Unplanned Facility Utility Outage Hours)/(24x365)**	
Electrical System			
Steam System			
Chilled Water System			