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Preface

The National Coal Council is a private, nonprofit advisory body, chartered under the Federal Advisory Committee Act.

The mission of the Council is purely advisory: to provide guidance and recommendations as requested by the United States Secretary of Energy on general policy matters relating to coal. The Council is forbidden by law from engaging in lobbying or other such activities. The National Coal Council receives no funds or financial assistance from the Federal government. It relies solely on the voluntary contributions of members to support its activities.

Members of the National Coal Council are appointed by the Secretary of Energy for their knowledge, expertise, and stature in their respective fields of endeavor. They reflect a wide geographic area of the United States (representing more than 30 states) and a broad spectrum of diverse interests from business, industry, and other groups, such as:

- large and small coal producers;
- coal users such as electric utilities and industrial users;
- rail, waterways, and trucking industries as well as port authorities;
- academia;
- research organizations;
- industrial equipment manufacturers;
- state government, including governors, lieutenant governors, legislators, and public utility commissioners;
- consumer groups, including special women's organizations;
- consultants from scientific, technical, general business, and financial specialty areas;
- attorneys;
- state and regional special interest groups; and
- Native American tribes.

The National Coal Council provides advice to the Secretary of Energy in the form of reports on subjects requested by the Secretary and at no cost to the Federal Government.

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Executive Summary

Purpose

By letter dated November 13, 2000, then-Secretary of Energy Bill Richardson requested that the National Coal Council conduct a study on measures which the government or the government in partnership with industry could undertake to improve the availability of electricity from coal-fired power plants. His letter requested that the Council address improving coal-fired generation availability in two specific areas:

- improving technologies at coal-fired electric generating plants to produce more electricity; and
- reducing regulatory barriers to using these technologies.

The Council accepted the Secretary's request and formed a study group of experts to conduct the work and draft a report. The list of participants of this study group can be found in Appendix D of the report.

Findings

The study group found the following.

- Nationally, approximately 40,000 megawatts of increased electrical production capability is possible now from existing coal-fired power plants.
- Such increased electricity supply can be available through the installation of standard improvements and clean coal technologies. This will have the important effect of increasing efficiency and decreasing emissions per megawatt from such modified plants, thereby improving air quality.
- Such plant efficiency and increased electricity production capability may only be realized if a return to historic regulatory policy is made.
- Coal-based electricity will be important for many years into the future. Therefore, regulations and policies employed should encourage the clean use of this resource through accelerated installation of more efficient, cleaner technologies.

The study was divided into two major sections: technology and regulatory reform. The focus of the technology section is on achieving more electricity from existing and new coal-fired power plants using technologies that improve efficiency, availability, and environmental performance. The discussion is divided into three subsections:

a) achieving higher availability/reliability in the existing fleet of coal-fired plants;
b) Increasing generation output of existing coal-fired plants; and
c) Determining opportunities for repowering existing facilities with clean coal technologies as well as building new advanced clean coal technology generation facilities.

Analysis of the U.S. utility industry infrastructure of coal plants reveals a significant potential for increasing generation capacity by taking well-tested measures to improve the reliability/availability of older facilities. This effort, which will come mainly from improvements on the steam generators of these older plants, can create 10,000 MW of new capacity.

Techniques to recover lost capacity and increase capacity above nameplate have been collected from a combination of research studies by utility industry organizations such as EPRI and actual case studies which are detailed in the report. The nameplate capacity of coal units older than 20 years is approximately 220,000 MW; however, due to derating, the existing capacity is only about 200,000 MW.

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This group of plants has the potential for both capacity restoration (about 20,000 MW) and/or improvement (about 20,000 MW). It is estimated that this increased capacity of 40,000 MW could be recovered within 36 months. This can allow the economy to grow while new generation facilities are sited, constructed, and brought into service.

For new coal-fired power generating capacity, Pulverized Coal Combustion in supercritical steam plants (a mature technology) is available with minimal emissions, high efficiency, and at very favorable total production cost.

Repowering of an old existing coal fired power plant with a single modern steam generating unit, equipped with commercially proven emissions controls results in significant reductions in the total amounts of emissions even while substantially increasing the total MWh output of the facility.

Integrated Gasification Combined Cycle (IGCC) has become a commercially available technology for both greenfield and repowering applications. IGCC is a clean, new technology option insensitive to fuel quality variation.

While natural gas will fuel the majority of new capacity additions during this time period there are currently about 321,000 MW of coal-fired capacity in service. While not all of this capacity can be targeted for the new technologies discussed in this report, it is estimated that 75% of it can be retrofitted with one of these technologies. This additional increase in capacity is estimated to be 40,000 MW and much of it could be brought on line in the next three years. This minimizes economic impacts while new generation facilities are sited, constructed, and brought into service without increasing emissions at existing facilities and, in some cases, lowering emissions. Approximately 25% of existing facilities can be targeted for repowering with much cleaner and more efficient coal-based power generation.

However, unless there is a significant change in regulatory interpretation and enforcement regarding the installation of new technologies at existing power plants, it is not likely that any of this additional low-cost, low emission electricity will be produced. The recent change in enforcement procedures by EPA (reinterpreting as violations of the Clean Air Act what had heretofore been considered routine maintenance at power plants) has had a direct and chilling effect on all maintenance and efficiency improvements and clean coal technology installations at existing power plants. EPA has brought legal action against 11 companies and 49 generation facilities since 1998 under the New Source Review section of the 1990 Clean Air Act. The companies involved believe that they were conducting routine maintenance needed to keep these plants in good condition. The result has been that no new efficiency, availability, or environmental improvement has occurred since 1998 when EPA changed its enforcement policy. A return to the historic interpretation of this one regulation alone would allow plant operators the opportunity to install technologies discussed in the report. If just a three percent increase in capacity could be achieved through reducing outages and increasing plant efficiency, it could result in over 11,500 MW of coal-based capacity being added to the current fleet while continuing the downward trend in emissions.

Several other existing regulations seem to be in conflict with the country's attempt to maximize the use of domestic energy sources. Environmental regulation should be harmonized with the energy and national security goals of the country.

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Recommendations

The National Coal Council strongly recommends that the country, with the Department of Energy in the lead, develop a clear, comprehensive energy policy that supports the maximum use of domestic fuel sources, continues to protect the environment by implementing strong but balanced environmental regulations, and harmonizes conflicting regulations affecting energy development and use. Government and industry should work in partnership to achieve the desired goals and remove those regulatory barriers that create obstacles to achieving those goals while preserving environmental performance.

Specifically, the Council recommends that the Department of Energy take the following actions.

- Initiate and lead a dialogue with EPA, with the goal of returning to the traditional pre-1998 interpretation of the New Source Review section of the 1990 Clean Air Act.
- Promote accelerated installation of clean and efficient technologies at new and existing coal-fired power plants.
- Initiate and lead a dialogue with EPA to promote coordinated regulations for ozone attainment into a single compliance strategy.
- Initiate and lead a dialogue with EPA and electricity generators to establish credible and uniform emissions targets, which will provide regulatory certainty for a sufficient period in the future to assure electricity generators that they can achieve a return on investments for performance and environmental improvements.
- Lead the country's effort to develop a clear, comprehensive, and secure energy policy that maximizes the use of domestic fuels, including coal, while continuing the downward trend in emissions.

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Achieving Higher Availability/Reliability From Existing Coal-Fired Power Plants

This section will focus on recommendations that will improve existing coal-fired power plants' reliability and availability to eliminate or reduce forced outages and extend the time between planned maintenance outages. This suggested availability improvement program is meant to restore the plants' infrastructure to a level that restores the original reliability of the plants. Implementation of these recommendations will allow the plants to increase generation output above recent historical output without increasing gross generating capability.

We will show from the use of industry sources on reliability (GADS/NERC) and generation capacity (EIA) that there is a significant opportunity for the utility industry to increase the generation output from our existing fleet of coal-fired power plants by restoring portions of the plant infrastructure to their original condition.

Analysis of the U.S. utility industry's coal-fired plant infrastructure reveals a significant opportunity for increasing electricity output from these plants by taking measures to improve the reliability/availability of the older facilities. Maintaining or restoring plants that are over 20 years old to a condition similar to plants that are under 20 years old can result in more reliable facilities that will be available to play an important role in supporting the increasing strain on our electrical system's reserve margins and electrical demand growth.

Specifically, our analysis has shown that this reliability improvement effort can create 10,000 MWs of equivalent generation capacity within our existing coal-fired fleet of plants. Of particular note is that over 90% of these MWs of capacity will come from component replacement and material upgrades of the boiler/steam generator at our facilities that are more than 20 years old. The U.S. EPA has focused on boiler/steam generator component replacement projects in its recent enforcement actions, applying New Source Review ("NSR") standards to repairs formerly considered routine maintenance, repair, or replacement. The potential regulatory consequences of the EPA's enforcement actions may prevent the utility industry from taking full advantage of this relatively inexpensive way to increase the availability of our national electric generating capacity, which could be implemented in a two to three year time frame.

The U.S. electric generating system's reserve margins have declined dramatically over the last 20 years. This situation has put pressure on the operators of our existing coal-fired fleet to restore, maintain, or improve the reliability and availability of their facilities to keep pace with the growing demand for electricity in the face of limited new capacity coming on line. The mandate for higher availability, lower forced outage rates, and longer time spans between planned outages is more critical today than ever in our history.

The causes of plant unavailability are well defined, and sound, technology-based solutions are commercially available to improve plant availability and help restore our historic reserve margins.

Causes of plant unavailability and recommendations for solutions have been generally categorized according to the magnitude of their impact on plant availability in the following list:

Area 1: Boiler/Steam Generator
The primary cause of unavailability of our coal-fired plants is the reliability of the boiler/steam generator. Severe duty on both the fire side and the water/steam side of the various heat transfer surfaces in the boiler/steam generator cause frequent unplanned outages and lengthening of planned outages to repair

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failures to these critical components of the power plant. Replacement of these components will significantly reduce outages and increase the facility's availability and total generation output capability. Examples of our recommendations for improving the availability of the boiler/steam generator are:

a. furnace wall panel replacements;
b. reheater component replacements;
c. primary superheater component replacements;
d. secondary superheater component replacements;
e. economizer replacements;
f. various header replacements;
g. furnace floor replacements;
h. cyclone burner replacements; and
i. incorporation of improved materials of construction for items a-h.

This area represents between 50% and 70% (depending on age, design, and operating history of the unit) of all lost generation from our coal-fired fleet. The industry data sources referenced above indicate that if improvements to the boilers/steam generators on our plants that are older than 20 years can be made to restore these facilities to the condition of plants that are under 20 years, we will benefit from an attendant improvement in reliability/availability. To help quantify this finding, plants older than 20 years are, on average, currently experiencing nearly 10% loss of achievable generation due to problems in the boiler/steam generator. This compares to approximately 5% loss for plants that are less than 20 years old. If we can recover only this differential through restoration of the boiler/steam generator, we will be taking advantage of nearly 9,000 MWs of available generation capacity in our existing coal-fired generating fleet. This figure is expected to increase significantly as our older generating units are dispatched more often to meet the growing demand for electricity considering the less than adequate new capacity coming on line.

Although the implementation of any (or all) of these recommendations will significantly increase plant availability, recent regulatory treatment of previously routine repairs, maintenance, and replacement as modifications by the EPA discourages utilities from pursuing these kinds of projects in their future plans for availability improvement for fear of triggering NSR with accompanying permitting and modeling requirements. NSR can radically undermine the economic feasibility of these projects, preventing recapture of lost generating capacity or increased reliability.

Area 2: Steam Turbine/Generator
Problems with the steam turbine/generator represent the second largest source of reduced generation capability in coal-fired plants. This area represents a 3% loss of generation compared to up to 10% for the boiler/steam generator. An interesting finding from our analysis is that the data sources referenced above show very little difference in loss of generation capability due to turbine/generator problems between plants older than 20 years and plants younger than 20 years. This phenomenon may be due to the regimented safety and preventative maintenance program typically mandated by turbine manufacturers and followed by plant owners for the steam turbine/generator.

Section 2 describes turbine/generator improvements (e.g., uprating) that can change gross plant outputs without changing the turbine/generator's relatively good track record on availability. In addition to turbine uprating, some of the general improvements that have occurred in steam turbine design will also improve the availability/reliability of existing steam turbines. Recommendations include:

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a. turbine blading replacements with improved shapes (CFD modeling) and materials of construction to increase turbine efficiency and reliability;
b. implementation of measures to reduce or eliminate droplet formation and the resultant blade erosion preserving turbine reliability and performance; and
c. turbine/generator inclusion in plant diagnostic and data acquisition system for predictive maintenance (reference area 7c below) to reduce unnecessary maintenance and associated outage time.

Area 3: Plant Auxiliaries

This area focuses on plant auxiliaries including the air heater, feedwater system, cooling water systems, electrical systems, etc. Plant auxiliaries cause approximately 1-2% of lost megawatt-hour (MWh) generation from our coal-fired plants over 20 years old. This can be improved to under 1% with restoration of critical components in this area of the plant. Some examples of recommendations for improved reliability and increased operating efficiencies in these areas are:

a. air heater or air heater basket replacement with the attendant modern sealing systems;
b. improved air heater surface design and cleaning system installation to address fouling;
c. feedwater heater retubing or replacement with upgraded materials to reduce failure rates; and
d. cooling tower fill improvements.

Area 4: Environmental (Focus on Electrostatic Precipitators)

Precipitator performance has the fourth largest impact on loss of plant availability. This problem almost always manifests itself in the form of load curtailment caused by the potential for opacity excursions. To exacerbate the problem, these curtailments typically occur at very critical capacity supply situations such as periods with high load requirements. Recommendations for mitigation are:

a. collection plate and electrode upgrades and/or replacement;
b. collection surface additions (new fields);
c. various flue gas treatment system installations;
d. addition of modern control system installations; and
e. general correction of leakage and corrosion problems.

Area 5: Fuel Flexibility

Many utilities have expanded their coal purchase specifications to leverage the variability in the cost of coal as a means of providing low-cost electricity to their customers. This practice, however, can have an adverse affect on plant reliability due to stress on the plant. It should be noted that although this area is not statistically recognized as a cause of loss of plant availability, fuel related problems are a major part of loss of availability from Area 1 "boiler/steam generator" due to such phenomena as boiler slagging/fouling, limited pulverizer throughput, reduced coal grindability, inadequate primary air systems, etc. Recommendations to reduce or eliminate these limitations are:

a. coal handling system upgrades to accommodate lower Btu coal;
b. mill upgrades to accommodate reduced grindability of coal;
c. ash (bottom and/or fly) system upgrades to accommodate higher ash coal or different ash classes;
d. additional furnace-cleaning equipment to mitigate different slagging and fouling characteristics of the coals;
e. draft system upgrades including FD fans, ID fans, combustion air temperature, and related electrical systems to accommodate higher gas volume flow rates; and

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f. precipitator upgrades to accommodate changes in fly ash resistivity and/or quantity.

Area 6: Boiler Water Treatment
This issue goes hand-in-hand with Area 1 described above. Performance of boiler heat transfer surface is highly dependent on the chemistry of the water/stream that keeps the surface cool. Upgrades of the boiler water treatment system should be coordinated with the upgrades described in Area 1. An added benefit of higher water purity standards is faster plant start-ups; and, therefore, a unit can come on-line more quickly and ramp up generation faster resulting in a higher overall generation output. In addition, water purity has a cascading effect increasing the reliability of feedwater heaters and turbine blades and improving condenser performance.

Area 7: Controls and Plant Diagnostic Systems
Modern digital control and diagnostic systems can improve heat rates (generation efficiency), lower emissions, reduce plant startup times, and provide valuable information for outage planning. Recommendations in this regard include:

a. replacement of outdated analog control with advanced digital control systems;
b. replacement and/or addition of instrumentation for better control of the unit over a wider range of loads and improved monitoring of critical system components for outage planning;
c. installation of plant diagnostic and data acquisition systems to perform predictive maintenance reducing unplanned outages and extending on-line time durations between planned outages; and
d. installation of turbine bypass system hardware and controls to facilitate lower load capabilities, faster unit start-ups and faster ramp rates increasing overall unit productivity.

Area 8: Plant Heat Rejection
For many plants, the highest capacity requirements of the year occur at the same time that they experience severe heat rejection limitations. Summertime cooling lake and river temperatures/water levels can cause load curtailments. Recommendations include:

a. water intake structure modifications to provide more flexibility during low water levels;
b. cooling tower additions to provide an alternate heat rejection mechanism; and
c. cooling lake design modifications (additional surface, redirected flow path, etc.) to increase heat rejection capability.

Summary

Restoration of our 20+-year-old coal-fired plants to a condition similar to those that are under 20 years through the recommendations described in these eight areas can create approximately 10,000 MWs of additional availability from existing assets. We would expect this number to grow significantly as we increase utilization of our older plants to meet growing demand. Without implementing these recommendations, the forecasted increases in utilization will accelerate failures in these older facilities increasing the need for the recommendations we have identified here.

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Of particular interest is that 90% of the increased availability identified will come from component replacement and other projects involving the boiler/steam generator. The boiler/steam generator has been the focus of the EPA's allegations in its recent reinterpretation of the New Source Review program as part of its power plant enforcement initiative.

Increasing Generation Output of Existing Units

The maximum demonstrated generating capacity (MDGC) of coal units older than 20 years, as identified above, is conservatively estimated to total approximately 220,000 MWs. The existing operating capacity is estimated to be 200,000 MWs (due to deratings). This group of plants has the potential for both capacity restoration (20,000 MWs) and/or capacity maximization (20,000 MWs). Thus, the total amount of potential increased MW output of this existing group of units is approximately 40,000 MWs. This increased capacity could be achieved within 36 months.

If all existing conditions resulting in a derating could be addressed, approximately 20,000 MWs of increased capacity could be obtained from regaining lost capacity due to unit deratings. This increase would be achieved using the approaches and techniques in Table 1 below.

Approximately an additional 20,000 MWs of capacity could be gained if it were possible to increase heat input and/or electrical output from generating equipment while still maintaining the acceptable design margins and allowable code ratings of the equipment. The approaches and techniques would be similar to those for regaining capacity, as indicated in Table 1.

These approaches and techniques could only be logically pursued by the facility owners if it was clearly understood that the increased availability and/or electrical output would not trigger New Source Review (NSR) and if repowering or construction of new clean coal technologies would be subject to the streamlined permitting authorized by the 1990 CAA Amendments.

The techniques to recover lost capacity and to increase capacity above MDGC have been collected from a combination of research studies by utility industry organizations (such as EPRI) and actual case studies (such as those outlined below) which had benefits for plant owners. They are summarized in Table 1 below.

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TABLE 1
Techniques and Approaches for Coal-Fired Power Plants Capacity Restoration and Increase

Capacity Increase Method	Capacity Restoration	Efficiency/ Capacity Increase	Fuel Conversion/ Repowering
Installation of improved air pollution control equipment	X	X	X
Steam turbine modernization improvements and upgrades	X	X	
Coal washing	X	X	
Coal switching	X	X	
Repowering with CFB technology			X
Consolidation of multiple, smaller inefficient units to larger, more efficient units		X	X
Operating above the nameplate but within the plant design	X	X	
Control system improvements	X	X	
Plant efficiency improvements	X	X	

The techniques and approaches listed in Table 1 have been implemented with proven results. The following highlights are from case studies.

- *SCR and FGD emissions control equipment was installed on a coal-fired generating station to reduce emissions of SOx and NOx. In order to offset the increased auxiliary load (16 MWs) of these new systems, an upgrade of the original 500-MW (nominal rating) steam turbine was performed. The upgrade consisted primarily of a new high-efficiency, high-pressure rotor with increased number of stages and an optimized steam path. The upgrade resulted in an output increase of approximately 15 MWs, almost offsetting the auxiliary load increase from the new emission controls.*
- *Turbine upgrades were completed on two 400-MW rated units to obtain an additional 25 MWs per unit. No additional steam was required from the boiler. No changes were made to the boiler. A more aerodynamic steam path through the turbine was designed and installed.*
- *Turbine upgrades were incorporated into another unit, nominally rated at 500 MWs achieving an additional 25 MWs. In this case, more steam had to be generated in the boiler and the steam turbine was upgraded.*
- *Coal cleaning is a process whereby a coal that is high in ash and sulfur is "washed." As a result, the coal is lower in both ash and sulfur content and higher in thermal value. The method consists of a multi-circuit wet process where water is used for screening and separation. Coal cleaning is a cost-effective means of separating ash and sulfur from coal, which in turn reduces opacity and SO_2 emissions. This enables one facility to continue to use local, lower cost, higher ash and sulfur coal and meet environmental limits. Without this coal cleaning process, the facility's load would be limited by approximately 10% due to opacity restrictions.*
- *Coal switching is an alternative to coal cleaning. In some cases where coal has been switched to reduce SOx emissions, the capacity may be impaired unless fuel handling systems are upgraded to allow efficient use of lower sulfur fuels.*
- *Repowering with CFB technology is an alternative to installing NOx and SOx emissions equipment. The use of this technique is highly site and fuel specific.*
- *Capacity increases can be accomplished by taking a brownfield site with several smaller old units, and repowering the site with a single large unit. This will require the full environmental permitting*

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process. It is a technique that is highly site specific and economically driven. To make the economics attractive, it is important that the units are running at low dispatch levels, so income losses are minimized, and the site can be readily cleared for construction of the larger unit.

- *Control system improvements can increase capacity in older plants. Modern control systems can improve efficiency and reduce emissions by optimizing the combustion process. General improvements to plant efficiency can be obtained by improved operating and maintenance practices along with targeted equipment improvements.*

Note: The additional 20,000 MW that can be achieved by capacity restoration described in this section includes the 10,000 MW of capacity that can be recovered due to deteriorated availability described earlier in the report.

Opportunities for Greenfield Sites and Repowering Existing Facilities with Pulverized Coal Power Generation

As a result of ongoing technology development, new and retrofitted pulverized coal power plants have achieved outstanding emissions performance for NOx, SOx, and particulates. Similarly, continued advances in the steam cycle continue to provide higher net plant efficiencies. As a result, new pulverized coal-fired power plants are now commercially available with minimal emissions and with very favorable total production cost. Repowering of an old existing coal-fired power plant with a single modern generating unit equipped with commercially proven emissions controls results in significant reductions in total tons of emissions, even while substantially increasing the total megawatt-hour output of the facility. A case study of repowering an actual old coal-fired plant with a unit utilizing current technology showed a 32% higher design capacity, achieving triple the total electrical output, an 87% reduction in tons of NOx and SOx up the stack, and a 42% reduction in total electricity production costs.

Pulverized Coal Technology Options
The configuration of today's state-of-the-art pulverized coal power plant is primarily dependent on the sulfur quantity of the coal to be utilized.

Low sulfur coals will most economically utilize a dry scrubber and baghouse for SO_2 and particulate control. Wet scrubbers can also be utilized with the benefit of producing a useful byproduct (gypsum).

Higher sulfur coals will utilize a wet scrubber and precipitator or baghouse for SO_2 and particulate control.

NOx emissions will be controlled by both Low NOx Burners (LNB)and Selective Catalytic Reduction (SCR).

The boiler/turbine steam cycle will vary from a standard subcritical cycle to an advanced supercritical cycle depending on project requirements and fuel costs.