Coal Power Plant Materials And Life Assessment Developments And Applications Woodhead Publishing Series In Energy

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Efficient Carbon Capture for Coal Power Plants
Clean Coal Engineering Technology
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Power Plant Engineering
Clean Power Generation from Coal

DESIREE BRENDEN

Struggling for Air ASM International The U.S. Department of Energy (DOE) and the Ohio Coal Development Office (OCDO) have undertaken a project aimed at identifying, evaluating, and qualifying the materials needed for the construction of the critical components of coal-fired boilers capable of operating at much higher efficiencies than current generation of supercritical plants. This increased efficiency is expected to be achieved principally through the use of advanced ultrasupercritical (A-USC) steam conditions up to 760°C (1400°F) and 35 MPa (5000 psi). A limiting factor to achieving these higher temperatures and pressures for future A-USC plants are the materials of construction. The goal of this project is to assess/develop materials technology to build and operate an A-USC boiler capable of delivering steam with conditions up to 760°C (1400°F)/35 MPa (5000 psi). The project has successfully met this goal through a focused long-term public-private consortium partnership. The project was based on an R & D plan developed by the Electric Power Research Institute (EPRI) and an industry consortium that supplemented the recommendations of several DOE workshops on the subject of advanced materials. In view of the variety of skills and expertise required for the successful completion of the proposed work, a consortium led by the Energy Industries of Ohio (EIO) with cost-sharing participation of all the major domestic boiler manufacturers, ALSTOM Power (Alstom), Babcock and Wilcox Power Generation Group, Inc. (B & W), Foster Wheeler (FW), and Riley Power, Inc. (Riley), technical management by EPRI and research conducted by Oak Ridge National Laboratory (ORNL) has been developed. The project has clearly identified and tested materials that can withstand 760°C (1400°F) steam conditions and can also make a 700°C (1300°F) plant more economically attractive. In this project, the maximum temperature capabilities of these and other available high-temperature alloys have been assessed to provide a basis for materials selection and application under a range of conditions prevailing in the boiler. A major effort involving eight tasks was completed in Phase 1. In a subsequent Phase 2 extension, the earlier defined tasks were extended to finish and enhance the Phase 1 activities. This extension included efforts in improved weld/weldment performance, development of longer-term material property databases, additional field (in-plant) corrosion testing, improved understanding of long-term oxidation kinetics and exfoliation, cyclic operation, and fabrication methods for waterwalls. In addition, preliminary work was undertaken to model an oxyfuel boiler to define local environments expected to occur and to study corrosion behavior of alloys under these conditions. This final technical report provides a comprehensive summary of all the work undertaken by the consortium and the research findings from all eight (8) technical tasks including A-USC boiler design and economics (Task 1), long-term materials properties (Task 2), steam- side oxidation (Task 3), Fireside Corrosion (Task 4), Welding (Task 5), Fabricability (Task 6), Coatings (Task 7), and Design Data and Rules (Task 8).

Coal-Fired Generation Oxford University Press

Coal-Fired Generation is a concise, up-to-date and readable guide providing an introduction to this traditional power generation technology. It includes detailed descriptions of coal fired generation systems, demystifies the coal fired technology functions in practice as well as exploring the economic and environmental risk factors. Engineers, managers, policymakers and those involved in planning and delivering energy resources will find this reference a valuable guide, to help establish a reliable power supply address social and economic objectives. Focuses on the evolution of the traditional coal-fired generation Evaluates the economic and environmental viability of the system with concise diagrams and accessible explanations

Emissions from a Coal-fired Power Plant

Academic Press
The U.S. Department of Energy (DOE) was given a mandate in the 1992 Energy Policy Act (EPACT) to pursue strategies in coal technology that promote a more competitive economy, a cleaner environment, and increased energy security. Coal evaluates DOE's performance and recommends priorities in updating its coal program and responding to EPACT. This volume provides a picture of likely future coal use and associated technology requirements through the year 2040. Based on near-, mid-, and long-term scenarios, the committee presents a framework for DOE to use in identifying R&D strategies and in making detailed assessments of specific programs. Coal offers an overview of coal-related programs and recent budget trends and explores principal issues in future U.S. and foreign coal use. The volume evaluates DOE Fossil Energy R&D programs in such key areas as electric power generation and conversion of coal to clean fuels. Coal will be important to energy policymakers, executives in the power industry and related trade associations, environmental organizations, and researchers.

Requirements for Materials R&D for Coal-fired Power Plant -into the 21st Century
Createspace Independent Pub
Conference proceedings covering the latest technology developments for fossil fuel power plants, including nickel-based alloys for advanced ultrasupercritical power plants, materials for turbines, oxidation and corrosion, welding and weld performance, new alloys concepts, and creep and general topics.

Power Plant Capital Costs, Current Trends and Sensitivity to Economic Parameters
EOLSS Publications
Due to their continuing role in electricity generation, it is important that coal power plants operate as efficiently and cleanly as possible. Coal Power Plant Materials and Life Assessment reviews the materials used in coal plants, and how they can be assessed and managed to optimize plant operation. Part I considers the structural alloys used in coal plants. Part II then reviews performance modelling and life assessment techniques, explains the inspection and life-management approaches that can be adopted to optimize long term plant operation, and considers the technical and economic issues involved in meeting variable energy demands. Summarizes key research on coal-fired power plant materials, their behavior under operational loads, and approaches to life assessment and defect management Details the range of structural alloys used in coal power plants, and the life assessment techniques applicable to defect-free components under operational loads Reviews the life assessment techniques applicable to components containing defects and the approaches that can be adopted to optimize plant operation and new plant and component design

Coal-Fired Electricity and Emissions Control Createspace Independent Pub
Tremendous tonnages of solid wastes are generated in coal-fired power plants. These amounts will increase greatly with increasing compliance with clean air laws and with conversion of petroleum-fired to coal-fired generating units.

Clean and Efficient Coal-fired Power Plants
Woodhead Publishing
Fossil-fuel power plants account for the majority of worldwide power generation. Increasing global energy demands, coupled with issues of ageing and

inefficient power plants, have led to new power plant construction programmes. As cheaper fossil fuel resources are exhausted and emissions criteria are tightened, utilities are turning to power plants designed with performance in mind to satisfy requirements for improved capacity, efficiency, and environmental characteristics. Advanced power plant materials, design and technology provides a comprehensive reference on the state of the art of gas-fired and coal-fired power plants, their major components and performance improvement options. Part one critically reviews advanced power plant designs which target both higher efficiency and flexible operation, including reviews of combined cycle technology and materials performance issues. Part two reviews major plant components for improved operation, including advanced membrane technology for both hydrogen (H2) and carbon dioxide (CO2) separation, as well as flue gas handling technologies for improved emissions control of sulphur oxides (SOx), nitrogen oxides (NOx), mercury, ash and particulates. The section concludes with coverage of high-temperature sensors, and monitoring and control technology that are essential to power plant operation and performance optimisation. Part three begins with coverage of low-rank coal upgrading and biomass resource utilisation for improved power plant fuel flexibility. Routes to improve the environmental impact are also reviewed, with chapters detailing the integration of underground coal gasification and the application of carbon dioxide (CO2) capture and storage. Finally, improved generation performance is reviewed with coverage of syngas and hydrogen (H2) production from fossil-fuel feedstocks. With its distinguished international team of contributors, Advanced power plant materials, design and technology is a standard reference for all power plant engineers and operators, as well as to academics and researchers in this field. Provides a comprehensive reference on the state-of-the-art gas-fired and coal-fired power plants, their major components and performance improvement options Examines major plant components for improved operation as well as flue gas handling technologies for improved emissions control Routes to improve environmental impact are discussed with chapters detailing the integration of underground coal gasification

Boiler Materials for Ultra Supercritical Coal Power Plants American Society of Mechanical Engineers

Concern over the effects of airborne pollution, green house gases, and the impact of global warming has become a worldwide issue that transcends international boundaries, politics, and social responsibility. The 2nd Edition of Coal Energy Systems: Clean Coal Technology describes a new generation of energy processes that sharply reduce air emissions and other pollutants from coal-burning power plants. Coal is the dirtiest of all fossil fuels. When burned, it produces emissions that contribute to global warming, create acid rain, and pollute water. With all of the interest and research surrounding nuclear energy, hydropower, and biofuels, many think that coal is finally on its way out. However, coal generates half of the electricity in the United States and throughout the world today. It will likely continue to do so as long as it's cheap and plentiful [Source: Energy Information Administration]. Coal provides stability in price and availability, will continue to be a major source of electricity generation, will be the major source of hydrogen for the coming hydrogen economy, and has the potential to become an important source of liquid fuels. Conservation and renewable/sustainable energy are important in the overall energy picture, but will play a lesser role in helping us satisfy our energy demands today. Dramatically updated to meet the needs of an ever changing energy market, Coal Energy Systems, 2nd Edition is a single source covering policy and the engineering involved in implementing that policy. The book addresses many coal-related subjects of interest ranging from the chemistry of coal and the future engineering anatomy of a coal fired plant to the cutting edge clean coal technologies being researched and utilized today. A 50% update over the first edition, this new book contains new chapters on processes such as CO_2 capture and sequestration, Integrated Gasification Combined Cycle (IGCC) systems, Pulverized-Coal Power Plants and Carbon Emission Trading. Existing materials on worldwide coal distribution and quantities, technical and policy issues regarding the use of coal, technologies used and under development for utilizing coal to produce heat, electricity, and chemicals with low environmental impact, vision for utilizing coal well into the 21st century, and the security coal presents. Clean Liquids and Gaseous Fuels from Coal for Electric Power Integrated Gasification Combined Cycle (IGCC) systems Pulverized-Coal Power Plants Advanced Coal-Based Power Plants Fluidized-Bed Combustion Technology CO_2 capture and sequestration

Advances in Ultra-low Emission Control Technologies for Coal-Fired Power Plants
John Wiley & Sons

This book presents the evolution toward advanced coal-fired power plants. Advanced power plants with an efficiency level of 45% are today commercially available and even more efficient plants are in their development phase. Considering that presently many pulverized coal-fired power plants operate with an efficiency of about 32%, an improvement of more than 40% specific coal consumption and CO_2 discharge can be achieved. Before trying to apply as a secondary measure the use of carbon sequestration, it seems that this 40% specific CO_2 discharge reduction as a primary measure can much easier be achieved. The effect of power generation on the environment can be drastically improved by the use of flue gas cleanup systems in advanced pulverized coal-fired power plants (SO_2 emission reduction from 40 to 1.4 lb/MWh and NO_x emission reduction from 7.5 to 0.64 lb/MWh). With an increased number of coal-fired plants, CO_2 discharge and emissions can be reduced, even with an increase of electric power generation in the US by 38% over the next 20 years. Even though the book concentrates on pulverized coal-fired power plants, it also discusses and compares other options like fluidized-bed combustion and coal gasification.

Solid Wastes from Coal-fired Power Plants Elsevier

This book has been derived from the work of several professors in the nuclear and power industry all of whom have been directly involved with the industry as managers or consultants. The text has been written as educational material and many of the individual chapters have been written as course material for advanced university courses. Also several chapters include material related to plant operation which is prescribed for operator training. Hence it bridges the gap between academic study and practical training. While it is not intended to be comprehensive in all respects it does provide an overview of the topic with sufficient technical depth for a general understanding of power plant technology and a basis for further study in a particular area. When used as a reference in this way each chapter can stand alone and be read independently of the others. Overall it meets the general philosophy of EOLSS in providing a source of knowledge for sustainable development and technological progress for educators and decision makers

National Energy Policy Elsevier

Coal- and gas-based power plants currently supply the largest proportion of the world’s power generation capacity, and are required to operate to increasingly stringent environmental standards. Higher temperature combustion is therefore being adopted to improve plant efficiency and to maintain net power output given the energy penalty that integration of advanced emissions control systems cause. However, such operating regimes also serve to intensify degradation mechanisms within power plant systems, potentially affecting their reliability and lifespan.Power plant life management and performance improvement critically reviews the fundamental degradation mechanisms that affect conventional power plant systems and components, as well as examining the operation and maintenance approaches and advanced plant rejuvenation and retrofit options that the industry are applying to ensure overall plant performance improvement and life management.Part one initially reviews plant operation issues, including fuel flexibility, condition monitoring and performance assessment. Parts two, three and four focus on coal boiler plant, gas turbine plant, and steam boiler and turbine plant respectively, reviewing environmental degradation mechanisms affecting plant components and their mitigation via advances in materials selection and life management approaches, such as repair, refurbishment and upgrade. Finally, part five reviews issues relevant to the performance management and improvement of advanced heat exchangers and power plant welds.With its distinguished editor and international team of contributors, Power plant life management and performance improvement is an essential reference for power plant operators, industrial engineers and metallurgists, and researchers interested in this important field. Provides an overview of the improvements to plant efficiency in coal- and gas-based power plants Critically reviews the fundamental degradation mechanisms that affect conventional power plant systems and components, noting mitigation routes alongside monitoring and assessment methods Addresses plant operation issues including fuel flexibility, condition monitoring and performance assessment

Thermal Power Plants - Volume I EOLSS Publications

For most of the twentieth century, the primary use of coal in the United States was for electric power generation, and for most of the history of power generation in the United States, coal has been the dominant fuel used to produce electricity. Even as recently as 2011, coal was the fuel used for almost 42% of power generation in the United States accounting for 93% of coal use. Industrial uses represented the remaining 7%. However, in April 2012, coal's share of the power generation market dropped to about 32% (according to Energy Information Administration statistics), equal to that of natural gas. Coal was the fuel of choice because of its availability and the relatively low cost of producing electricity in large, coal-burning power plants which took advantage of coal's low-priced, high energy content to employ economies of scale in steamelectric production. However, coal use for power generation seems to be on the decline, and the magnitude of coal's role for power generation is in question. Two major reasons are generally seen as being responsible: the expectation of a dramatic rise in natural gas supplies, and the impact of environmental regulations on an aging base of coal-fired power plants. A recent drop in natural gas prices has been enabled by increasing supplies of natural gas largely due to horizontal drilling and hydraulic fracturing (i.e., fracking) of shale gas formations. If the production can be sustained in an environmentally acceptable manner, then a long-term, relatively inexpensive supply of natural gas could result. Decreased natural gas prices are lowering wholesale electricity prices, stimulating a major switch from coal to gas-burning facilities. The electric utility industry values diversity in fuel choice options since reliance on one fuel or technology can leave electricity producers vulnerable to price and supply volatility. However, an “inverse relationship” may be developing for coal vs. natural gas as a power generation choice based on market economics alone, and policies which allow one fuel source to dominate may come at the detriment of the other. Coal-fired power plants are among the largest sources of air pollution in the United States. More than half a dozen separate Clean Air Act programs could possibly be used to control emissions, which makes compliance strategy potentially complicated for utilities and difficult for regulators. Because the cost of the most stringent available controls, for the entire industry, could range into the tens of billions of dollars, some power companies have fought hard and rather successfully to limit or delay regulations affecting them, particularly with respect to plants constructed before the Clean Air Act Amendments of 1970 were passed. The expected retirement of approximately 27 GW of coal-fired capacity by 2016 has been reported to the Energy Information Administration (EIA) by coal plant owners and operators, accounting for approximately 8.5% of U.S. coal-fired capacity. While the costs of compliance with new Environmental Protection Agency regulations are a factor, several other issues are cited by coal plant owners and operators as contributing to these retirement decisions including the age of coal-fired power plants, flat to modest electricity demand growth, the availability of previously underutilized natural gas combined-cycle power plants, and the lower price of natural gas due to shale gas development. Even coal plants which have made significant modifications to meet existing EPA regulations are being closed or mothballed due to a combination of low natural gas prices, and the inability to sell power into other markets. EIA expects coal to be a significant part of the U.S. power generation industry's future to well past 2030. But given price competition from natural gas, and emerging environmental regulations, that role will likely be smaller than in recent decades. Coal-fired generation is likely to face a challenging future.

Advances in Materials Technology for Fossil Power Plants ASM International

The continued use of coal as a means of generating electricity and an increasing demand for cleaner, more efficient energy production has led to advances in power plant technology. Ultra-supercritical coal power plants reviews the engineering, operation, materials and performance of ultra-supercritical coal power plants. Following a chapter introducing advanced and ultra-supercritical coal power plants, part one goes on to explore the operating environments, materials and engineering of ultra-supercritical coal power plants. Chapters discuss the impacts of steam conditions on plant materials and operation, fuel considerations and burner design, and materials and design for boilers working under supercritical steam conditions. Chapters in part two focus on improving ultra-supercritical coal power plant performance and operability. Ash fouling, deposition and slagging in ultra-supercritical coal power plants are highlighted along with pollution control measures and the estimation, management and extension of the life of ultra-supercritical power plants. Further chapters provide an economic and engineering analysis of a 700°C advanced ultra-supercritical pulverised coal power plant and discuss CO2 capture-ready ultra-supercritical coal power plants. Ultra-supercritical coal power plants is a comprehensive technical reference for power plant operators and engineers, high-temperature materials scientists, professionals in the power industry who require an understanding of ultra-supercritical coal power plants and researchers and academics interested in the field. Provides a comprehensive reference on the developments, materials, design and operation of ultra-supercritical power plant Considers the degradation issues affecting this type of plant, as well as emissions control and CO2 capture technology; improved plant controls critical to improved operation and environmental performance Contains operational assessments for plant safety, plant life management, and plant economics

Materials for Supercritical Pulverised Coal-fired Power Plant CRC Press

The principal objective of this project is to develop materials technology for use in ultrasupercritical (USC) plant boilers capable of operating with 760 C (1400 F), 35 MPa (5000 psi) steam. This project has established a government/industry consortium to undertake a five-year effort to evaluate and develop of advanced materials that allow the use of advanced steam cycles in coal-based power plants. These advanced cycles, with steam temperatures up to 760 C, will increase the efficiency of coal-fired boilers from an average of 35% efficiency (current domestic fleet) to 47% (HHV). This efficiency increase will enable coal-fired power plants to generate electricity at competitive rates (irrespective of fuel costs) while reducing CO2 and other fuel-related emissions by as much as 29%. Success in achieving these objectives will support a number of broader goals. First, from a national prospective, the program will identify advanced materials that will make it possible to maintain a cost-competitive, environmentally acceptable coal-based electric generation option. High sulfur coals will specifically benefit in this respect by having these advanced materials evaluated in high-sulfur coal firing conditions and from the significant reductions in waste generation inherent in the increased operational efficiency. Second, from a national prospective, the results of this program will enable domestic boiler manufacturers to successfully compete in world markets for building high-efficiency coal-fired power plants.

Power Plant Life Management and Performance Improvement Elsevier

Carbon Capture and Storage is a key technology for a sustainable and low carbon economy. This book unites top academic and industry researchers in search for commercial concepts for CCS at coal power ploants. This reference focuses on power plant technology and ways to improve efficiency. It details the three principal ways of capturing the CO2 produced in power plants: oxyfuel combustion, postcombustion and precombustion, with the main part concentrating on the different approaches to removing carbon dioxide. Wtih an eye on safety, the authors explain how the three parts of the CCS chain work - capture, transport and storage - and how they can be performed safely. The result is specific insights for process engineers, chemists, physicists and materials engineers in their relevant fields, as well as a sufficiently broad scope to be able to understand the opportunities and implications of the other disciples.

Coal Woodhead Publishing

Advances in Ultra-low Emission Control Technologies for Coal-Fired Power Plants discusses the emissions standards of dust, SO2, NOx and mercury pollution, also presenting the key technologies available to control emissions in coal-fired power plants. The practical effects of ultra-low emissions projects included help the reader understand related implications in plants. Emphasis is placed on 300MW subcritical, 600MW subcritical, 660MW supercritical and 1000MW ultra-supercritical coal-fired units. The influence of different pollutant control units, such as wet electrostatic precipitator, desulfurization equipment and the electrostatic precipitator are also analyzed, and the pollutant levels before and after retrofitted ultra-low emissions are compared throughout. Provides a unique analysis of advanced technologies, such as dust-removal, desulfurization and denitrification used for ultra-low emissions in coal-fired power plants Introduces emission standards for dust, SO2, NOx and Mercury pollution from coal-fired power plants in China, the US and Europe Provides solutions to reducing emissions based on technological advances in China Analyzes the environmental and economic effects of these technologies

Coal-Fired Power Generation Handbook ASM International

Coal-Fired Electricity and Emissions Control: Efficiency and Effectiveness discusses the relationship between efficiency and emissions management, providing methods for reducing emissions in newer and older plants as coal-fired powered plants are facing increasing new emission control standards. The book presents the environmental forces driving technology development for coal-fired electricity generation, then covers other topics, such as cyclone firing, supercritical boilers, fabric filter technology, acid gas control technology and clean coal technologies. The book relates efficiency and environmental considerations, particularly from a technology development perspective. Features time tested methods for achieving optimal emission control through efficiency for environmental protection, including reducing the carbon footprint Covers the regulations governing coal-fired electricity Highlights the development of the coal-fired technologies through regulatory change

Thermal Power Plants - Volume II Elsevier

Coal accounts for approximately one quarter of world energy consumption and of the coal produced worldwide approximately 65% is shipped to electricity producers and 33% to industrial consumers, with most of the remainder going to consumers in the residential and commercial sectors. The total share of total world energy consumption by coal is expected to increase to almost 30% in 2035. This book describes the challenges and steps by which electricity is produced form coal and deals with the challenges for removing the environmental objections to the use of coal in future power plants. New technologies are described that could virtually eliminate the sulfur, nitrogen, and mercury pollutants that are released when coal is burned for electricity generation. In addition, technologies for the capture greenhouse gases emitted from coal-fired power plants are described and the means of preventing such emissions from contributing to global warming concerns. Written by one of the world's leading energy experts, this volume is a must-have for any engineer, scientist, or student working in this field, providing a valuable reference and guide in a quickly changing field.

Chemical and Mineralogical Characteristics of Milled Coal, Ashes, and Stack-emitted Material from Unit No. 5, Battle River Coal-fired Power Station, Alberta, Canada National Academies Press

This book has been derived from the work of several professors in the nuclear and power industry all of whom have been directly involved with the industry as managers or consultants. The text has been written as educational material and many of the individual chapters have been written as course material for advanced university courses. Also several chapters include material related to plant operation which is prescribed for operator training. Hence it bridges the gap between academic study and practical training. While it is not intended to be comprehensive in all respects it does provide an overview of the topic with sufficient technical depth for a general understanding of power plant technology and a basis for further study in a particular area. When used as a reference in this way each chapter can stand alone and be read independently of the others. Overall it meets the general philosophy of EOLSS in providing a source of knowledge for sustainable development and technological progress for educators and decision makers.

Coal Power Plant Materials and Life Assessment Springer Science & Business Media

Coal power plants generate about half of the United States' electricity and are expected to remain a key energy source. Coal power plants also account for about one-third of the nation's emissions of carbon dioxide (CO_2), the primary greenhouse gas that experts believe contributes to climate change. Current regulatory efforts and proposed legislation that seek to reduce CO_2 emissions could affect coal power plants. Two key technologies show potential for reducing CO_2 emissions: (1) carbon capture and storage (CCS), which involves capturing and storing CO_2 in geologic formations, and (2) plant efficiency improvements that allow plants to use less coal. The Department of Energy (DOE) plays a key role in accelerating the commercial availability of these technologies and devoted more than $600 million to them in fiscal year 2009. Congress asked GAO to examine (1) the maturity of these technologies; (2) their potential for commercial use, and any challenges to their use; and (3) possible implications of deploying these technologies. To conduct this work, GAO reviewed reports and interviewed stakeholders with expertise in coal technologies. DOE does not systematically assess the maturity of key coal technologies, but GAO found consensus among stakeholders that CCS is less mature than efficiency technologies. Specifically, DOE does not use a standard set of benchmarks or terms to describe the maturity of technologies, limiting its ability to provide key information to Congress, utilities, and other stakeholders. This lack of information limits congressional oversight of DOE's expenditures on these efforts, and it hampers policymakers' efforts to gauge the maturity of these technologies as they consider climate change policies. In the absence of this information from DOE, GAO interviewed stakeholders with expertise in CCS or efficiency technologies to identify their views on the maturity of these technologies. Stakeholders told GAO that while components of CCS have been used commercially in other industries, their application remains at a small scale in coal power plants, with only one fully integrated CCS project operating at a coal plant. Efficiency technologies, on the other hand, are in wider commercial use. Use of both technologies is, however, contingent on overcoming a variety of economic, technical, and legal challenges. In particular, with respect to CCS, stakeholders highlighted the large costs to install and operate current CCS technologies, the fact that large scale demonstration of CCS is needed in coal plants, and the lack of a national carbon policy to reduce CO_2 emissions or a legal framework to govern liability for the permanent storage of large amounts of CO_2. With respect to efficiency improvements, stakeholders highlighted the high cost to build or upgrade such coal plants, the fact that some upgrades require highly technical materials, and plant operators' concerns that changes to the existing fleet of coal power plants could trigger additional regulatory requirements. CCS technologies offer more potential to reduce CO_2 emissions than efficiency improvements alone, and both could raise electricity costs and have other effects. Most stakeholders told GAO that CCS would increase electricity costs, and some reports estimate that current CCS technologies would increase electricity costs by about 30 to 80 percent at plants using these technologies. DOE has also reported that CCS could increase water consumption at power plants. Efficiency improvements offer more potential for near term reductions in CO_2 emissions, but they cannot reduce CO_2 emissions from a coal plant to the same extent as CCS. GAO recommends that DOE develop a standard set of benchmarks to gauge and report to Congress on the maturity of key technologies. In commenting on a draft of this report, DOE concurred with our recommendation.