



The National Coal Council
Power for America from America

Reliable & Resilient

The Value of Our Existing Coal Fleet

**An Assessment of Measures to Improve
Reliability & Efficiency While Reducing Emissions**



May 2014



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Southern Company

LEAD AUTHORS

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NCC EXECUTIVE VICE PRESIDENT & CHIEF OPERATING OFFICER

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The National Coal Council is a Federal Advisory Committee to the U.S. Secretary of Energy. The NCC advises, informs and makes recommendations to the Secretary on matters requested by the Secretary relating to coal or the coal industry.

The National Coal Council

The National Coal Council (NCC) was chartered in 1984 based on the conviction that an industry advisory council on coal could make a vital contribution to America's energy security. NCC's founders believed that providing expert information could help shape policies relevant to the use of coal in an environmentally sound manner. It was expected that this could, in turn, lead to decreased dependence on other less abundant, more costly and less secure sources of energy.

These principles continue to guide and inform the activities of the Council. Coal has a vital role to play in the future of our nation's electric power and energy needs. Our nation's primary energy challenge is to find a way to balance our social, economic and environmental needs.

Throughout its 30-year history, the NCC has maintained its focus on providing guidance to the Secretary of Energy on various aspects of the coal industry. NCC has retained its original charge to represent a diversity of perspectives through its varied membership and continues to welcome members with extensive experience and expertise related to coal.

The NCC serves as an advisory group to the Secretary of Energy, chartered under the Federal Advisory Committee Act (FACA), providing advice and recommendations to the Secretary of Energy on general policy matters relating to coal and the coal industry. As a FACA organization, the NCC does not engage in lobbying activities.

The principal activity of the NCC is to prepare reports for the Secretary of Energy at his/her request. During its 30-year history, the NCC has prepared more than 30 studies for the Secretary, at no cost to the Department of Energy. All NCC studies are publicly available on the NCC website.

Members of the NCC are appointed by the Secretary of Energy and represent all segments of coal interests and geographic distribution. The NCC is headed by a Chair and Vice Chair who are elected by the members. The Council is supported entirely by voluntary contributions from NCC members and receives no funds from the federal government. Studies are conducted solely at the expense of the NCC and at no cost to the government.

The National Coal Council values the opportunity to represent the power, the pride and the promise of our nation's coal industry.



The National Coal Council ***Power for America from America***

May 14, 2014

The Honorable Dr. Ernest Moniz
U.S. Secretary of Energy
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585

Dear Mr. Secretary:

On behalf of the members of the National Coal Council (NCC), we are pleased to submit to you pursuant to your letter dated January 31st, 2014, the report “Reliable and Resilient: The Value of Our Existing Coal Fleet.” The study’s primary focus was to assess what industry and the Department of Energy, separately and jointly, can do to enhance the capacity, efficiency and emissions profile of the existing coal generation fleet in the United States through the application of new and advanced technology. The study also examines the job implications of modification and addition of equipment at existing coal power plants. Other issues addressed in the report include benefits afforded by the existing fleet and changes that could impact those benefits in the future.

The NCC study was conducted during the winter of 2013-2014. The severe cold weather events experienced while the study was underway reinforced the importance of retaining and maintaining coal generation assets in order to reliably and affordably meet the electricity needs of U.S. residents and businesses. The major lesson learned from the Polar Vortex experience is that the availability and operation of coal units now scheduled for retirement over the next two years enabled the power sector to meet demand during periods of harsh weather.

NCC’s assessment of the existing U.S. coal fleet supports the findings that:

- The current 310 GW fleet of coal-fired power plants underpins economic prosperity in the U.S., providing direct economic and macroeconomic benefits; energy supply and price stability; environmental benefits through continuous technology advancements; and job-creating opportunities.
- Coal plant closures and increasing reliance on natural gas for power generation will adversely impact price stability and resource supply.
- New Source Review (NSR) regulations adversely impact generators’ decisions and ability to enhance plant efficiency, reduce emissions and improve overall operations and capacity.
- Collaborative RD&D efforts (DOE and industry) can enhance the ability of the coal fleet to improve its flexibility and reliability, to increase its efficiency and to reduce its emissions profile.

The need for RD&D is vital to support marketplace shifts and public policy objectives:

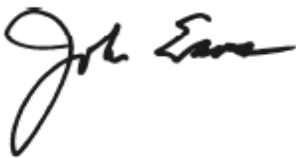
- Increasing deployment of intermittent renewable energy technologies, competition from other fossil fuels, use of non-design coals and continued use of older coal generation technologies will lead to increased operation of base load units in a cycling mode for which they were not designed.
- Modest improvements in efficiency are possible with existing technologies to improve heat transfer, reduce heat losses and make better use of low quality heat. More advanced improvements, if technically and commercially viable, could significantly enhance efficiency.
- Challenges arise in complying with emerging regulations for control of traditional pollutants when new control regimes create secondary, follow-on emissions issues.
- Existing coal plants were not designed or located with CCS in mind; the ability to retrofit these plants for CCS is problematic. More research is needed to commercialize CCS retrofit potential; improved efficiencies provide an interim path in the meantime.

The U.S. benefits from having a diverse portfolio of electricity sources. The Energy Information Administration (EIA) projects very little new coal capacity will be built in the U.S. through 2040. Therefore, maintaining coal's role in this diversified portfolio will likely rest on industry's ability to continue safe and economical operation of the existing fleet, while making the changes necessary to ensure continued environmental compliance.

Past challenges to coal generation, such as the need to reduce emissions of sulfur dioxide, nitrogen oxides and mercury, were met through collaborative efforts between the public sector and the private sector to develop new technologies. The question posed by this report is – Can this be done again? The National Coal Council believes that “Yes, it can be done and yes, it must be done.”

Thank you for the opportunity to conduct this study and produce this report. The Council stands ready to address any questions you may have on the recommendations it contains.

Sincerely,

A handwritten signature in black ink, appearing to read "John W. Eaves". The signature is fluid and cursive, with a large initial "J" and "E".

John W. Eaves
NCC Chair
(May 2012-May 2014)



The Secretary of Energy
Washington, DC 20585

January 31, 2014

Mr. John Eaves
Chairman, The National Coal Council
1730 M Street NW, Suite 907
Washington, DC 20036

Dear Chairman Eaves:

I am writing today to request that the National Coal Council (NCC) conduct a new study that assesses the existing U.S. coal fleet. In order to meet U.S. economic, energy and environmental goals, power generators are interested in pursuing opportunities to improve the capacity, efficiency and emissions profiles of existing coal assets employing performance optimization tools, techniques and technology retrofits.

The assessment of the existing U.S. coal fleet would address the following question: What can industry and the Department of Energy, separately and jointly, do to facilitate enhancing the capacity, efficiency and emissions profiles of the existing coal generation fleet in the United States through application of new and advanced technology? Such a study would also address the jobs implications of modification and addition of equipment at existing coal fired power plants.

Upon receiving this request and establishing your internal study working groups, please advise me of your schedule and work plan for completion of this study.

Sincerely,

A handwritten signature in black ink, appearing to read "Ernest J. Moniz".

Ernest J. Moniz

Reliable & Resilient

The Value of Our Existing Coal Fleet

Study Work Group & Review Team

EXECUTIVE MANAGEMENT TEAM

Jeff Wallace, Southern Company Services – Study Chair
Fred Palmer, Peabody Energy – Coal Policy Committee Chair
Bill Brownell, Hunton & Williams – Coal Policy Committee Vice Chair

TECHNICAL WORK GROUP CHAIR

Steve Wilson, Southern Company

STUDY LEADERSHIP TEAM

Steve Wilson, Southern Company – Study Technical Chair
Doug Carter, Independent Energy Consultant – Lead Author
J. Edward Cichanowicz, Independent Engineering Consultant – Principal Author
Stu Dalton, EPRI – Principal Author
Janet Gellici, National Coal Council

STUDY REVIEW TEAM

Don Gaston, PSEG Fossil
Matt Usher, American Electric Power
Mark Wilson, Tri-State Generation & Transmission

Todd Adkins, Patriot Coal

Sy Ali, Clean Energy Consulting

Janos Beer, MIT

Roger Bezdek

Management Information
Services Inc. (MISI)

Lisa Bradley, AECOM

Frank Clemente, Penn State

Chase Crawford, Southern Company

Mike Durham, ADA-ES

Fred Eames, Hunton & Williams

Clark Harrison, CH2M Hill

Bob Hilton, ALSTOM Inc.

Makram Jaber, Hunton & Williams

Holly Krutka, Shenhua Group

Rich Lopriore, PSEG Fossil

Rafic Minkara, Headwaters

Ram Narula, Consultant

Bob Purgert, Energy Industries of Ohio

Mark Schoenfield, Jupiter Oxygen

Rick Smith, Ameren Energy

Ben Yamagata

Coal Utilization Research Council

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COAL POLICY COMMITTEE

Robert O. Agbede, Chester Engineers
Sy Ali, Clean Energy Consulting
Richard Bajura, West Virginia University
Theodore K. Barna, Barna Solutions, LLC
Janos M. Beer, Massachusetts Institute of Technology
Jacqueline F. Bird
F. William Brownell, Esq., Hunton & Williams
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Stu Dalton, EPRI
Jack Daly, Sargent & Lundy
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John Dwyer
John W. Eaves, Arch Coal, Inc.
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John S. Fischer, Breakthrough Energy, LLC
Mark Fraley, FirstEnergy Solutions Corp
Robert D. Gabbard, PPL EnergyPlus, LLC
Guy Gorney
Manoj K Guha, Energy & Environmental Services
Clark D. Harrison, CH2M Hill
William Hoback, IL Office of Coal Development
Gerald (Jerry) A. Hollinden
Clarence Joseph Hopf, PPL EnergyPlus
Marty Irwin, IN Center for Coal Tech. Research
Michael Karmis, Virginia Tech
Norman Kettenbauer, GenPower Services
Klaus Lambeck, Public Utilities Commission of Ohio
John T. Long, Connemara Ltd.
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Jason Makansi, Pearl Street, Inc.
John S. Mead
Nancy Mohn, ALSTOM
Ram G. Narula
Kenneth J. Nemeth, Southern States Energy Board
Jerry J. Oliver, Global Tech Management Services
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Robert M. Purgert, Energy Industries of Ohio
Mark Schoenfield, Jupiter Oxygen Corporation
Gregory A. Workman, Dominion Resources

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EXECUTIVE SUMMARY



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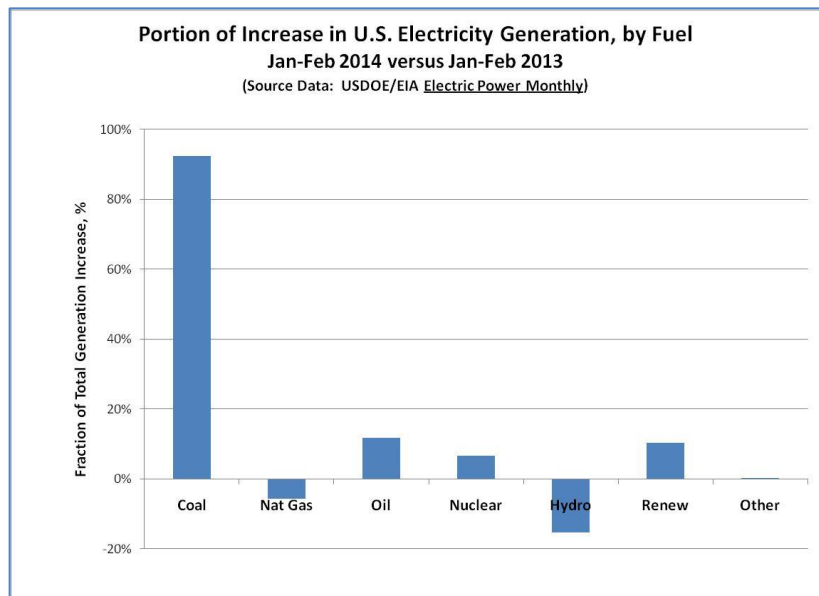
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Executive Summary

1. Introduction

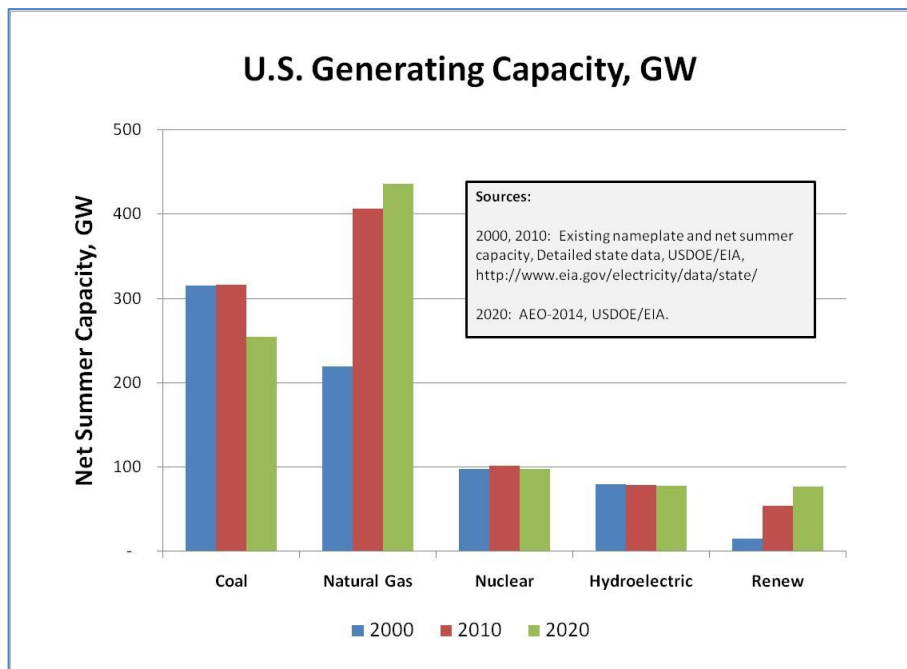
The existing fleet of coal-fired power plants underpins economic prosperity in the U.S. Coal-based generation has dominated U.S. electricity supply for nearly a century. In 2013, coal again led U.S. generation, at 39%. Low cost coal keeps U.S. electricity prices below those of other free market nations. For example, in 2013 the average price of residential and industrial electricity in the U.S. was one-half to one-third the price of electricity in Germany, Denmark, Italy, Spain, the UK and France (see Table B.1). These price differentials translate into more disposable income for U.S. consumers, and a competitive edge for U.S. industry in global markets. If the existing coal fleet were replaced with the next cheapest alternative generating source, natural gas combined cycle power plants, a conservative estimate of the impact on the U.S. economy would be a 1.5% drop in Gross Domestic Product (GDP) and a loss of 2 million jobs per year. Characteristics of the existing U.S. coal fleet, and its benefits to society (including employment benefits, economic benefits, and benefits to energy security and grid reliability), are discussed in Section B of this report.

The “Polar Vortex” weather events of January and February 2014 demonstrated the contribution of the existing coal fleet, including those units currently scheduled for retirement over the next 2 to 3 years, to the reliability of the U.S. electricity grid. AEP reported that it deployed 89% of its coal units scheduled for closure, and Southern Company reported use of 75% of its coal units scheduled for closure. Use of these units enabled utilities to meet customer demand during a period when already limited natural gas resources were diverted from electricity production to meeting residential heating needs. Nationwide, over 90% of the increase in power generation in January and February 2014 (versus January and February 2013) came from the existing coal fleet.



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The U.S. benefits from having a diverse portfolio of electricity sources. However, the Energy Information Administration (EIA) projects very little new coal capacity will be built in the U.S. through 2040.ⁱ EIA projects that coal's share of total generation will decline from 39% in 2013 to an average of 37% for 2014-2040,ⁱⁱ assuming current environmental regulations.¹ Therefore, maintaining coal's role in this diversified portfolio will likely rest on industry's ability to continue safe and economical operation of the existing fleet, while making the changes necessary to ensure continued environmental compliance.



The existing coal fleet will face a number of serious challenges over the next few years. Some derive from the demographics of the fleet: it is getting older. The average U.S. coal-fired power plant has operated for 39 years.² Older generating units are often financially and in some cases technically, less capable of accommodating large capital investments to meet new regulatory requirements and as

units age their maintenance costs increase. The age of a generating unit is not a dispositive criterion in decisions related to the continued operation of that unit, but age is one of several important considerations influencing decisions regarding capital investments to meet future reliability and environmental compliance requirements.

Other challenges relate to meeting new environmental requirements as existing coal-fired power plants must cope with a range of new air pollution regulations, as well as federal requirements related to water use, wastewater treatment and solid waste management. Additional rules are being developed to limit CO₂ emissions. Thirty states now have renewable portfolio standards or other measures like energy efficiency resource standards that tend to reduce the use of and/or place additional pressures on existing coal-fired generators in the midst of more intermittent renewable generation and additional states have established “goals” rather than standards.

¹ Current regulations do not include, for example, rules now under development for CO₂ limits, restrictions on cooling water intake structures, and coal combustion residuals (ash) management.

² Capacity-weighted age, as of 2014, excluding retirements in 2013-14.

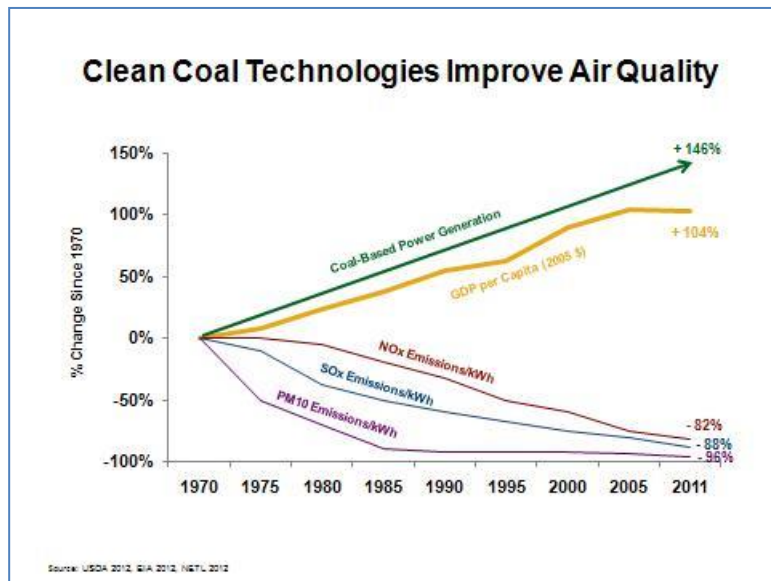
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Still other challenges are market oriented, such as the recent lack of growth in electricity demand and strong competition from other generation sources, including natural gas based generation. These factors are felt most strongly in competition for new generating assets, but existing units are also affected. The combination of market factors and regulatory requirements will likely result in many existing coal-fired units being retired earlier than their economic lifespan, and others operating in a “cycling”³ or “flexible” mode in future years, rather than in a traditional “base load” mode. All of these challenges will pressure existing coal-based units to operate more cost-effectively and with greater flexibility if they are to remain in service.

Past challenges to coal generation, such as the need to reduce emissions of sulfur dioxide, nitrogen oxides and mercury, were met through collaborative efforts between the public sector and the private sector to develop new technologies. The terms “Flue Gas Desulfurization”, “Selective Catalytic Reduction” and “Activated Carbon Injection” were not part of the nation’s lexicon in 1970. Today these systems, developed through industry/government

collaboration, are standard equipment on new coal-fired power plants and have been widely deployed on existing units as well. Additionally, for every dollar of federal funds invested in coal RD&D, thirteen dollars of benefits accrued to the nation. Moreover, RD&D in advanced coal technologies can produce products for sale abroad, enhancing U.S. manufacturing and improving the nation’s balance of trade.

The question posed by this report is: Can this be done again? More specifically, **what technological solutions can be developed by the private and/or the public sector to enhance the existing coal generation fleet’s capacity, efficiency and emissions, as well as the jobs outlook for those that operate and supply those assets?**



³ For purposes of this report, the term “cycling” includes both startup transitions and operational changes from minimum to maximum capability.

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This report considers three main categories of technologies that, if developed, would assist the existing coal fleet in meeting many of its challenges:

- Technologies enabling more flexible operation for units that will be cycling and undergoing more frequent startups and shutdowns while maintaining reliability.
- Technologies to improve the efficiency of the existing fleet. More efficient power plants tend to emit less of all pollutants, but the focus of this report is more efficient technologies that reduce emission of CO₂.
- Technologies, other than improved efficiency, that reduce emissions from coal-fueled power plants. These technologies would address traditional gaseous, liquid and solid waste streams, as well as CO₂ emissions from existing coal-fired units.

a. Flexibility and Reliable Operation

Most large existing coal-fired power plants were originally designed to run in “base load” mode. With very low costs of operation, these units ranked high in the “economic dispatch” of units available to satisfy electricity demand by residential, commercial and industrial power consumers. As noted above, changing market conditions have led to the expectation that many of these base load designed units will, in the future, be used in a cycling mode resulting in significant operational and maintenance issues. Some may operate at base load during peak demand seasons (winter and summer), and be cycled or brought off the grid during other seasons.

Exacerbating the need for more flexibility in the remaining fleet is the expected retirement of many of the older, smaller coal fired units that have provided cycling operation in the past. About 20% of the generating capacity of the existing coal fleet is expected to retire by 2020 due to market conditions and currently applicable regulations (most of this capacity will retire by 2016, when compliance with the recent Mercury and Air Toxics Standards (MATS) is required). Two-thirds of this retiring capacity is composed of units with subcritical steam cycles, less than 300 megawatt (MW) in size. Recently these smaller older units have contributed to fleet resiliency during times of high systems demand: units now scheduled for retirement were operated near full capacity. Additional regulations now under development may increase retirements of these more flexible units.

Many of today’s sophisticated emission control systems are designed to operate under relatively constant conditions and at high load factors. For example, selective catalytic reduction systems for nitrogen oxides (NOx) control require that flue gases have a minimum temperature for the catalyst to be effective. Operating at low load may not meet this criterion with currently available catalysts, monitoring and control systems. Systems for capturing sulfur dioxide (SO₂) may operate at lower thermal efficiency at partial load, and may create new, less manageable wastewater issues and coal combustion products.

Technologies to address these problems can take several forms. One is the development of improved materials, such as better alloys and metal coatings that are stronger and less sensitive to corrosion. Stronger materials allow thinner-walled components and thinner walls result in less damage from the stress of changing temperatures that accompany cycling operation.

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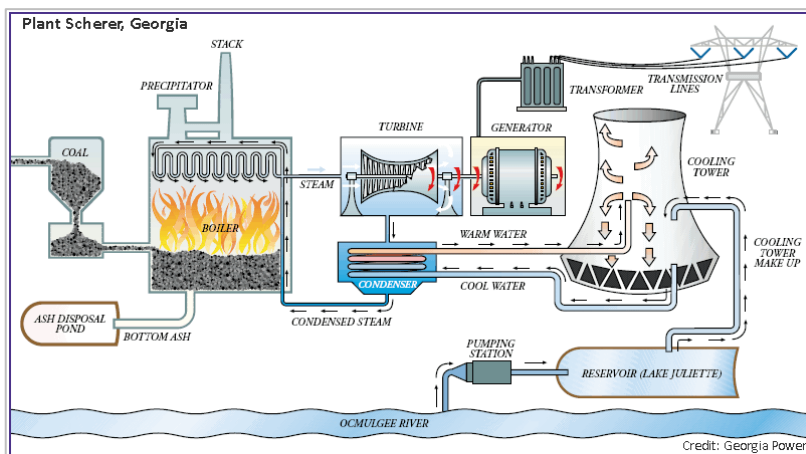
Another type of technology involves improved sensors and controls. These can both automate the optimization of multiple plant operating parameters under rapidly changing load conditions, as well as help in predicting problems before a critical component fails. Improved sensors and monitors can allow operation closer to design margins and with greater reliability by detecting performance or life degradation. Improved non-destructive diagnostic systems would also aid reliability. Existing “asset management” programs need to be modified to reflect the effects of cycling on plant economics and reliability.

An additional class of potentially useful technologies would treat coal to reduce moisture or trace element content – factors that can impact unit availability and performance, particularly when a unit is designed to use coals from a variety of sources. Enabling flexible operation at a unit that uses coals from different sources will be more difficult and costly.

In general, training programs and studies using lessons learned and best practices can assist plant operators and maintenance personnel with the improved technologies and procedures that are critical to success.

b. Improving Unit Efficiency

Decisions to commit resources to energy efficiency measures generally consider a range of factors. These include the obvious positive impacts on fuel use and reduced emissions; potentially negative impacts related to new source review policy (discussed in Section C.4.); and



less obvious potential effects on operational flexibility such as achieving minimum loads, higher ramp rates, increased outage durations. Increasing attention to emissions of carbon dioxide (CO₂) will provide greater impetus to improve efficiency.

A number of technical reports have considered specific measures that could potentially

be applied within a coal-fired power plant. For example, coal could potentially be dried using waste heat, making the boiler more efficient. Steam turbines could potentially be refit with modern and more efficient multistage rotors. In addition, corrosion and deposition on major heat transfer components (boiler tubes and condensers) could potentially be reduced, making heat transfer in those components more efficient.

On some units, alkali materials can be injected into flue gases to reduce acidity that would otherwise present corrosion problems at low temperatures, thereby potentially allowing greater heat recovery from flue gases. Improved sensors and controls could potentially allow a plant to operate closer to conditions optimal for higher efficiency. Variable speed drives could potentially be used to make motors more efficient, particularly at lower load.

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The New Source Review (NSR) permitting program unintentionally limits investments in efficiency. Some actions to improve efficiency at an existing power plant could lead to a designation of the change as a “major modification” subjecting the unit to NSR permitting requirements. These requirements usually entail additional environmental expenditures (that can reduce efficiency), as well as delays associated with processing the permit. In general, if a plant owner expects that an efficiency improvement would lead to such a designation, the efficiency project will not be pursued as the resulting permitting process would be extensive and the compliance requirements would be onerous and likely too stringent to be practicable. Unfortunately, this prospect has all but eliminated RD&D that would more than marginally innovate the fleet.

“As applied to existing power plants and refineries, EPA concludes that the NSR program has impeded or resulted in the cancellation of projects which would maintain and improve reliability, efficiency and safety of existing energy capacity. Such discouragement results in lost capacity, as well as lost opportunities to improve energy efficiency and reduce air pollution.” ~ EPA

c. Reducing Emissions

In addition to the discussion on efficiency, which tends to reduce all emissions, this report considers two other categories of emission reductions at existing coal-fueled power plants: traditional emission controls and reduction of CO₂ emissions through use of carbon capture and storage (CCS).

i. Traditional Emission Controls

The existing coal fleet is generally well equipped with systems designed to control emissions of particulate matter, nitrogen oxides and sulfur dioxide. These systems and recent additions aimed at hazardous air pollutants (HAPs) are effective at removing other pollutants such as mercury. Existing units also comply with regulations related to thermal emissions to bodies of water that supply cooling water at the power plant, wastewater emissions and solid waste management. However, recently proposed or adopted regulations will lead to more stringent emission reduction requirements, and often reduction of emissions in one media (e.g., air) will result in new pollution control issues in another media (e.g., wastewater). With these new rules in mind, this report recommends several areas in which collaborative RD&D could develop improved technologies to mitigate emissions. Such collaborative efforts have been highly successful in developing and commercializing technologies in the past, including flue gas desulfurization, low-NO_x burner systems, selective catalytic reduction of NO_x and mercury control technologies. Moreover, for every dollar of federal funding in coal technology development, approximately thirteen dollars of benefits accrued to the nation.^{iv}

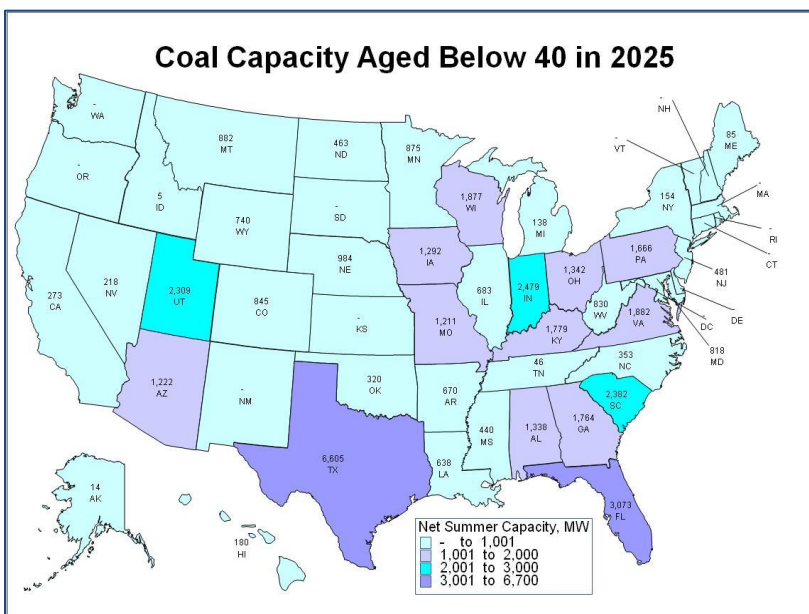
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ii. Retrofitting CCS

The Obama administration's stated long term climate goal is to reduce U.S. greenhouse gas (GHG) emissions by 83% (relative to 2005 emissions) by 2050.^v Although U.S. coal-fueled power plants contributed only 3% of global GHG emissions in 2012, fossil energy-based electricity generation contributed 31% of total U.S. GHG emissions in 2012 (23% from coal-fired units; 8% from natural gas-fired units).^{vi} These numbers suggest any future reduction requirements will target a large reduction in CO₂ emissions from fossil energy-based power. One possible pathway for such a reduction is the development and deployment of CCS technologies. Much progress on developing CCS systems for coal-fired power plants has been achieved by the collaborative RD&D program managed by the U.S. Department of Energy (DOE). However, as indicated in DOE's program plans for CCS, much remains to be done.

Previous NCC reports have addressed CCS control technology and identified the primary shortcomings of CCS technologies currently under development to be:

- They have not been demonstrated at commercial scale on a power plant.
- The knowledge base on saline storage and enhanced oil recovery (EOR) remains limited, and there are unresolved non-technical barriers to both.
- The current technologies are too costly, impose significant energy penalties and can significantly increase cooling water requirements for the generating unit.
- There are numerous challenges related to the integration of CCS on existing units.
- Significant uncertainty exists regarding the characteristics, feasibility and availability of geologic storage opportunities.
- Significant legal and regulatory challenges remain to be resolved, including those related to the long-term stewardship and liability of geologically stored CO₂.

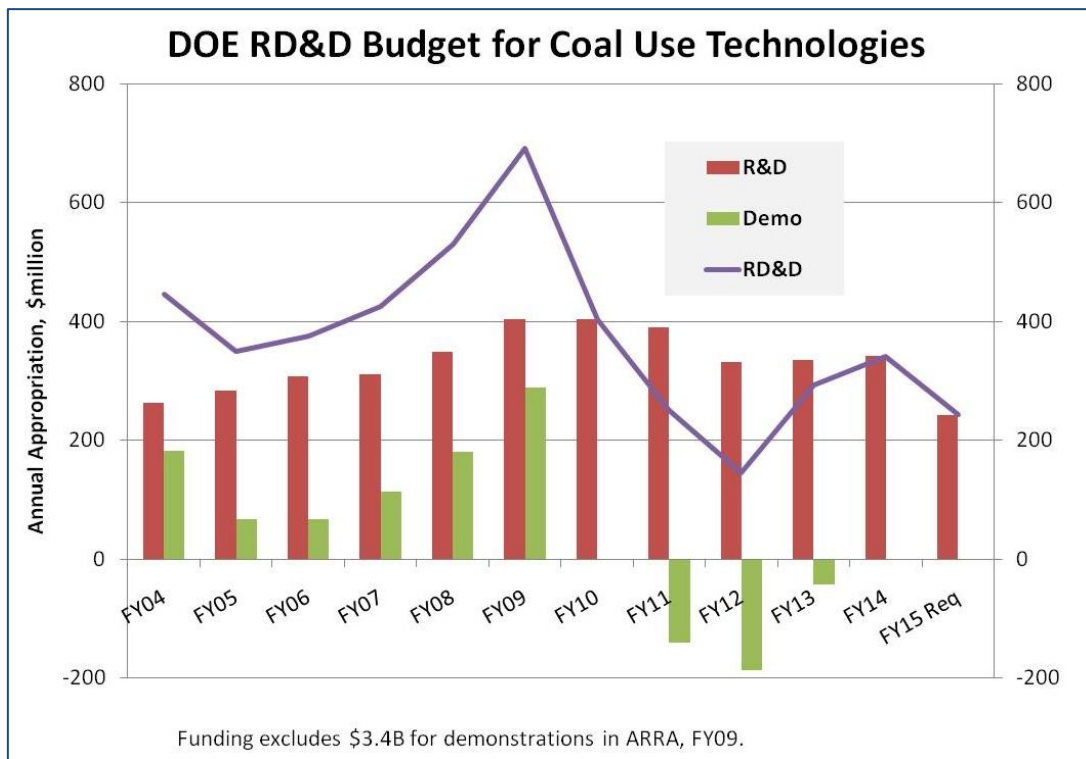


Some of these problems are being addressed to some extent by ongoing RD&D. With adequate funding, DOE plans to have 2nd Generation CCS technologies (at lower cost than current technologies) available to begin demonstration in 2020-2025, and available for commercial use a few years later. However, retrofitting existing units (or repowering them with CCS systems) poses the additional problem that there is a limited time window for development of needed technologies. **Less than 10% of the existing coal fleet will be under 40 years of age in 2030.**

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As discussed in Section B, the age profile of existing coal-fired power plants varies by region, and by type of utility. For example, coal units owned by rural cooperatives tend to be newer than those operated by investor-owned utilities. Decisions on whether to retrofit capital intensive hardware, such as CCS systems, are based on multiple economic factors, some of which relate to the remaining useful life of potential retrofit candidates, and some of which are highly uncertain when projected 15 years into the future. These uncertainties include the capital cost of competing electricity generation technologies, new environmental requirements and the future price of natural gas. Nevertheless, from both an economic perspective and from the perspective of meeting climate change mitigation goals, much less costly CCS technologies are needed much sooner than the current program provides.

In addition, although DOE has a robust research and development (R&D) program, there does not appear to be a plan to obtain the resources needed to move research products to the more costly demonstration stage of technology development.



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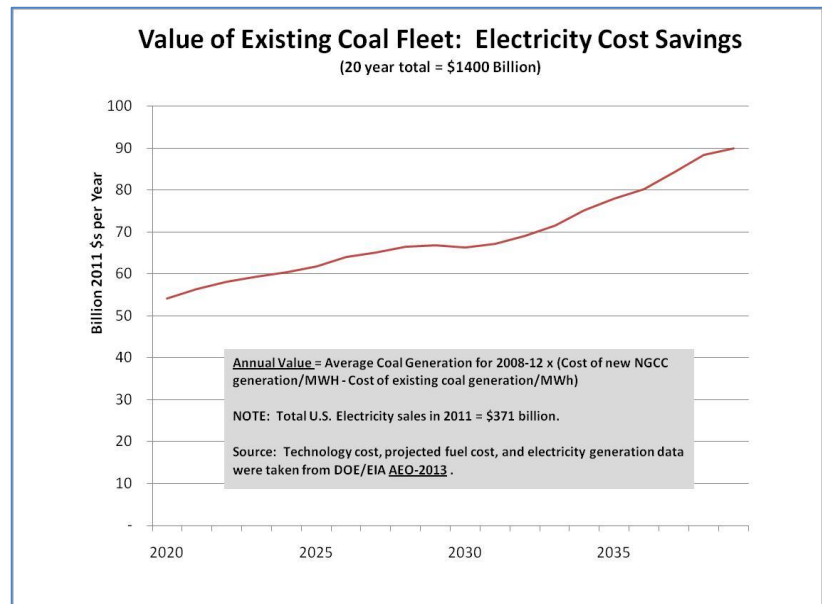
2. Key Findings and Recommendations

The following key findings and recommendations are taken from the more detailed listings of findings and recommendations in Sections B, C and D of the NCC study.

a. The Value of the Existing Coal Generation Fleet

Findings

- The U.S. existing coal fleet continues to play a vital role in meeting our nation’s electric power needs. The extreme cold weather events of the winter of 2013-2014 highlight the need to maintain a diverse portfolio of generation options in order to ensure the availability of affordable, reliable power for residential and industrial uses.
- The historical deployment of advanced coal technologies demonstrates that coal generation can be increased while simultaneously reducing emissions.
- Retrofitting advanced environmental technologies and enhancing efficiency at existing coal plants could result in the creation of 44,000 to 110,000 jobs, depending on the degree of efficiency improvement achieved.



Recommendations

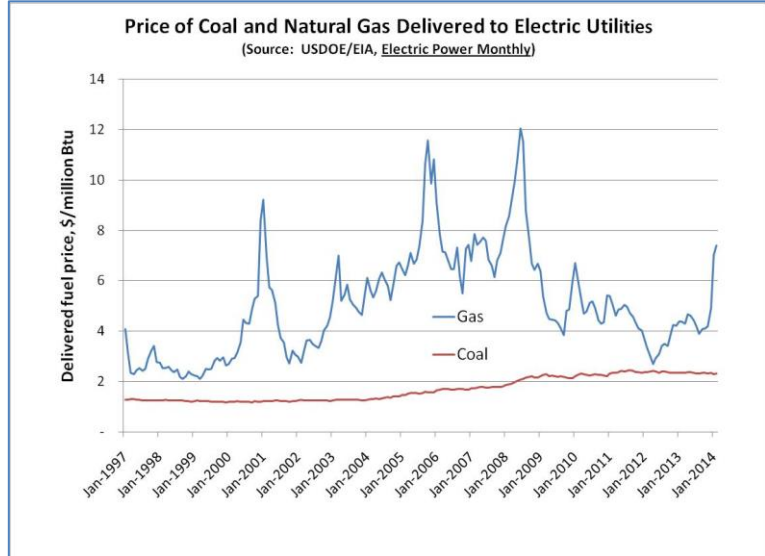
- DOE should lead collaborative efforts with industry to assess the impacts of the 2014 polar vortex experience on power prices, availability and reliability.
- DOE should ensure that basic federal energy policy assessments, such as the Quadrennial Energy Review^{vii} and the President’s Advanced Manufacturing Initiatives^{viii} consider the impact of lower priced electricity facilitated by coal-fired power plants, and include an assessment of the value of diversity of generation sources and how pending coal plant retirements are likely to impact power prices, availability and reliability.
- DOE should lead collaborative efforts with industry to evaluate the implications of generation diversity on the President’s advanced manufacturing initiatives and efforts to enhance the global competitiveness of U.S. manufacturers.

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b. Changes that Could Impact the Existing Coal Generation Fleet

Findings

- Natural gas prices continue to be volatile, reinforcing an historical trend. Past efforts by both industry and government have not produced accurate predictions of future natural gas prices. Increased reliance on natural gas for power generation will impact price stability and resource supply.
- The price of coal per unit of energy delivered to electric power plants is less than the price of delivered natural gas. EIA projects that coal's price advantage will increase through at least 2040.



- New Source Review (NSR) regulations impact generators' decisions and ability to enhance plant efficiency, reduce emissions and improve overall operations/capacity. The delay and cost associated with obtaining an NSR permit tend to eliminate efficiency enhancement projects as viable options.
- Many of the challenges facing the existing coal fleet are technology based, and would benefit from DOE-led collaborative RD&D with industry. Funding requirements, particularly for demonstration projects are significant.
- EIA projects that 60 gigawatts (GW) of coal capacity will be retired by 2020, relative to 2010, based on projected market conditions, but not considering a series of recently proposed and not yet promulgated environmental regulations applicable to coal-fired power plants.
- Notwithstanding retirement of approximately 20% of the coal fleet capacity, EIA projects that under current regulations, coal-fired generation will remain approximately the same from 2010 through 2040.

Recommendations

- DOE should work with the EPA to eliminate New Source Review-related barriers that disincentivize generators to pursue efficiency improvements that would otherwise reduce emissions, increase capacity and enhance plant operations.
- DOE should seek input from industry research associations such as the Electric Power Research Institute (EPRI) and Coal Utilization Research Council (CURC), regarding priority research needs and the appropriate balance between research, development and demonstration of technologies relevant to the existing coal fleet.

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c. Improving Fleet Flexibility and Reliability

Findings

- In the future, factors such as increased deployment of intermittent renewable energy technologies, competition from other fossil fueled generation, use of non-design coals and the increasing age of the coal generation fleet will lead to increased operation of base load-designed coal generation units in a cycling mode.
- Greater understanding of failure mechanisms leading to tube leaks, component failures and other malfunctions leading to forced outages and reduced equipment life are necessary to maintain system reliability.
- Similarly, major emission control subsystems were generally designed for steady state operation and may not operate as reliably or effectively under changing load conditions.

Recommendations

- DOE should lead collaborative RD&D efforts with industry to develop assessment tools, improved sensors and controls, non-destructive evaluation, remaining life evaluation and an understanding of damage mechanisms.
- DOE should lead collaborative RD&D efforts with industry to enhance practical knowledge about operating flue gas desulfurization (FGD) and selective catalytic reduction (SCR) systems in a cycling environment, with a range of off-specification coals.
- DOE should lead collaborative RD&D efforts with industry to develop advanced materials that are more corrosion resistant and have increased strength. Stronger heat exchanger materials can be designed with thinner walls that are more tolerant of temperature cycling.

d. Increasing the Efficiency of the Existing Fleet

Findings

- Modest improvements in efficiency are possible at some units with existing technologies to improve heat transfer, reduce heat losses and make better use of low quality heat.
- New Source Review policy is a major barrier to implementing known efficiency measures at existing coal-fueled power plants.
- The addition of a topping or bottoming cycle to an existing generating unit's Rankine cycle, if proven feasible and developed commercially, could deliver significant efficiency improvements. Practical systems could require up to 10 years to commercialize.

Recommendations

- DOE should lead collaborative RD&D efforts with industry to develop topping and bottoming cycles that can be retrofit to existing power plants.
- DOE should work with regulatory agencies to remove NSR barriers to efficiency upgrades.
- DOE should lead collaborative RD&D efforts with industry to develop best practices manuals for potential application of currently known techniques to improve power plant efficiency.

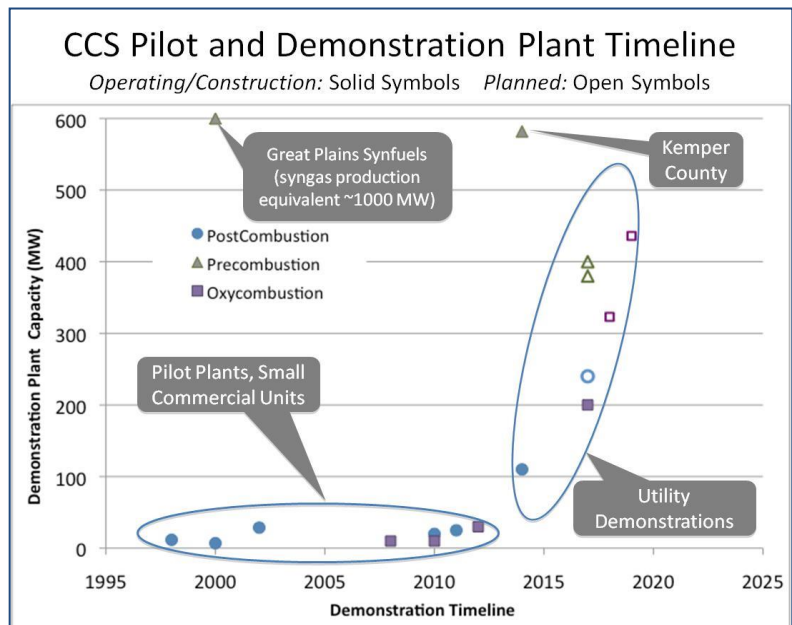
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e. Reducing Emissions from the Existing Fleet

Findings

- Past federal RD&D to improve the performance and reduce emissions from coal-fired power plants has yielded \$13 of benefits for every dollar of federal investment.
- Proposed standards for wastewater effluents from existing coal-fueled power plants are not achievable under all operating conditions (e.g., for wastewaters with high oxidation reduction potential) using existing technologies.
- Some of the challenges posed by emerging regulations for traditional pollutants are the result of other emission control systems. For example, bromine or other chemicals introduced to enhance mercury removal from flue gases can alter wastewater streams from air pollution control devices.
- The recently proposed CO₂ New Source Performance Standards (NSPS) rules specified more stringent monitoring and reporting requirements for power plant CO₂ used for EOR versus “natural” CO₂ used for EOR. According to a major EOR operator, “the proposed NSPS rule will foreclose – not encourage – the use of CO₂ captured by emissions sources in EOR operations.”^{ix} It is unclear whether these rules, when finalized, will allow the flexibility needed by EOR operators in practical EOR projects.

- Substantial progress has been made on CCS systems for CO₂ capture from power plants, but much more work is needed before these systems can be a practical commercial option for existing power plants. Cost, system integration and legal framework issues are all major barriers to deployment of currently available technologies.
- While many of the more technical aspects and costs of the CCS process are fairly well categorized, the costs and risks associated with monitoring, mitigation and verification (MM&V), permitting, site negotiation, property rights, liability, legal/contracting costs, costs of meeting legal or regulatory requirements, etc., are less well understood and quantified.



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Recommendations

- DOE should lead collaborative RD&D efforts with industry to develop:
 - technologies and mechanisms to meet additional requirements for wastewater effluents from existing coal-fueled power plants,
 - technologies to address control of secondary emissions from primary emission control systems, such as bromine and trace metals removed from flue gases that are discharged via wastewater streams, and
 - systems to conserve water and reduce cooling water environmental impacts from existing power plants.
- The need for accelerated solutions points to greater emphasis on hands-on test facilities that emulate the **National Carbon Capture Center** design concept.
- DOE should place much more emphasis on commercial scale demonstration of CCS systems, both capture and storage options.
- DOE should work with states and regulatory agencies to create a pragmatic legal framework for CO₂ storage, particularly in saline formations, and to avoid monitoring requirements that deter use of captured CO₂ in EOR applications.
- DOE should lead collaborative RD&D efforts with industry to analyze CO₂ storage related issues associated with meeting financial responsibility compliance per Class VI Underground Injection Control (UIC) regulations [40 CFR §146.85].



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ⁱ Annual Energy Outlook – 2014er, USDOE/EIA, December 16, 2013.

ⁱⁱ Ibid.

ⁱⁱⁱ Technical Support Document for the Advanced Notice of Proposed Rulemaking for Greenhouse Gases: Stationary Sources, Section VII, USEPA, June 5, 2008, Docketed item # EPA-HQ-OAR-2008-0318-0081.

^{iv} The Return on Investment of the Clean Coal Technology Program in the USA, R. Bezdek and R. Wendling, *Energy Policy*, March 2013, Vol. 54, pp. 104-112.

^v “By 2050, the Obama administration’s goal is to reduce U.S. greenhouse gas emissions approximately by 83 percent from 2005 levels.” U.S. Climate Action Report, 2010, (the 5th National Communication of the USA under the UNFCC), June 2010.

^{vi} Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012, USEPA, February 21, 2014.

^{vii} Obama Administration Launches Quadrennial Energy Review, The White House, January 9, 2014, <http://www.whitehouse.gov/the-press-office/2014/01/09/obama-administration-launches-quadrennial-energy-review> .

^{viii} White House Advanced Manufacturing Initiatives to Drive Innovation and Encourage Companies to Invest in the U.S., The White House, July 17, 2012, <http://www.whitehouse.gov/the-press-office/2012/07/17/fact-sheet-white-house-advanced-manufacturing-initiatives-drive-innovati> .

^{ix} Subpart RR Flaws Preclude EPA’s Reliance on CO2-EOR in the Proposed NSPS Rule, Denbury, (undated), quoted by Rep. Weber at hearing of House Environment Subcommittee, Committee on Science, Space, and Technology, March 12, 2014.