



»» FOSSIL FORWARD

Revitalizing CCS

Bringing Scale and Speed to CCS Deployment

FEBRUARY 2015



Fossil Forward - Revitalizing CCS Bringing Scale and Speed to CCS Deployment

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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.

National Coal Council – Fossil Forward



The Secretary of Energy
Washington, DC 0585

May 15, 2014

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

Chairman Eaves:

I am writing to request the National Coal Council (NCC) conduct a study that assesses the value of the Department of Energy's Carbon Sequestration Program. The capture of carbon dioxide (CO₂) emissions from the combustion of fossil fuels used in electrical power generation is critical to the future of fossil fuels, particularly coal, used in this country.

The assessment would address the following question: what is the industry's assessment of the progress made by the DOE and others regarding cost, safety, and technical operation of CCS/CCUS? In other words, how does industry see and accept major technical findings from the CCS/CCUS community, and how do those relate to DOE programs and investments.

In order to meet U.S. economic, energy and environmental goals, power generators are being called upon to enhance the environmental performance of fossil fueled plants. For coal, that enhanced environmental performance requires the application of CCS/CCUS technology. Therefore, an assessment based on technical soundness and results to date would provide a welcome perspective from leading companies with experience in CCS/CCUS technology.

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

Sincerely,

A handwritten signature in black ink, appearing to read "Ernest J. Moniz". The signature is fluid and cursive, with a long horizontal stroke at the end.

Ernest J. Moniz



February 26, 2015

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 May 15th, 2014, the report “Fossil Forward – Revitalizing CCS: Bringing Scale and Speed to CCS Deployment.” The study’s primary focus was to assess the value of the Department of Energy’s Carbon Sequestration Program. The study addresses the question: What is industry’s assessment of the progress made by the DOE and others regarding cost, safety, and technical operation of CCS/CCUS? NCC’s report provides an industry perspective on major technical findings from the CCS/CCUS community and how they relate to DOE programs and investments.

The principal theme of the NCC’s Fossil Forward study is that while the Department of Energy (DOE) is indisputably a world leader in the development of CCS technology, the DOE CCS/CCUS program has not yet achieved critical mass. While there have been some successes, there is a need for a substantial increase in the number of large-scale demonstration projects for both capture and storage technologies before either system approaches commercialization. Without adequate demonstration, there can be no commercialization.

The Key Recommendations from the Fossil Forward assessment are:

- In order to achieve CCS deployment at commercial scale, policy parity for CCS with other low carbon technologies and options is required.
- Technology and funding incentives must be significantly better coordinated to be effective.
- DOE program goals need far greater clarity and alignment with commercial technology and financing approaches used by industry.
- Funding for CCS RD&D is limited and must be enhanced and focused.
- Public acceptance continues to be a major hurdle and efforts to address public concerns must be accelerated.
- Control of greenhouse gas (GHG) emissions is an international issue in need of international initiatives.

National Coal Council – Fossil Forward

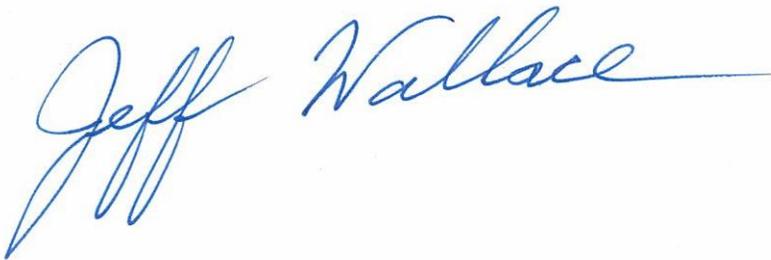
Today, deploying CCS/CCUS technology is costly. Tomorrow, not deploying CCS technology will exert an even greater cost, significantly increasing the cost of meeting of CO2 emission reduction goals and greatly hampering our efforts to do so. Without CCS, it is highly improbable that CO2 emissions reduction goals will be met. Equally important, without CCS projected costs of achieving these goals will be much higher.

To date, the DOE has been a world leader in advancing CCS technologies. Although DOE's annual budget is insufficient to fund all the first mover projects that are needed, there is no question that the dollars spent thus far have advanced and will continue to advance CCS. An international effort led by the U.S. is needed, but it must be supported financially and technically by the rest of the world.

CCS can be an enabling technology to protect the natural world while also placing the necessary value on human welfare. The National Coal Council applauds the U.S. Department of Energy's leadership to date and encourages a continued commitment to the commercial deployment of CCS/CCUS.

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 blue ink that reads "Jeff Wallace". The signature is fluid and cursive, with a long horizontal line extending from the end of the name.

Jeff Wallace
NCC Chair
(May 2014-December 2015)

Fossil Forward - Revitalizing CCS

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Bringing Scale and Speed to CCS Deployment

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Bringing Scale and Speed to CCS Deployment

Executive Summary

Charge to the Council

This report was prepared by the National Coal Council (NCC) in direct response to a request from the U.S. Secretary of Energy regarding the CCS program of the Department of Energy. The heart of that request was as follows:

“I am writing to request the National Coal Council (NCC) conduct a study that assesses the value of the Department of Energy's Carbon Sequestration Program. The capture of carbon dioxide (CO₂) emissions from the combustion of fossil fuels used in electrical power generation is critical to the future of fossil fuels, particularly coal, used in this country.

The assessment would address the following question: what is the industry's assessment of the progress made by the DOE and others regarding cost, safety, and technical operation of CCS/CCUS? In other words, how does industry see and accept major technical findings from the CCS/CCUS community, and how do those relate to DOE programs and investments?

In order to meet U.S. economic, energy and environmental goals, power generators are being called upon to enhance the environmental performance of fossil fueled plants. For coal, that enhanced environmental performance requires the application of CCS/CCUS technology. Therefore, an assessment based on technical soundness and results to date would provide a welcome perspective from leading companies with experience in CCS/CCUS technology.”

The May 2014 NCC report on the value of the existing coal fleet explained the importance of retaining coal as a fuel resource option for electric power generation. “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 U.K. and France. 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.”¹

¹ The National Coal Council, “The Value of Our Existing Fleet: An Assessment of Measures to Improve Reliability and Efficiency While Reduction Emissions”, May, 2014, <http://www.nationalcoalcouncil.org/NEWS/NCCValueExistingCoalFleet.pdf>

That report also pointed out the need for CCS/CCUS technology in order to meet proposed CO₂ emission reduction goals in the future.

Key Findings

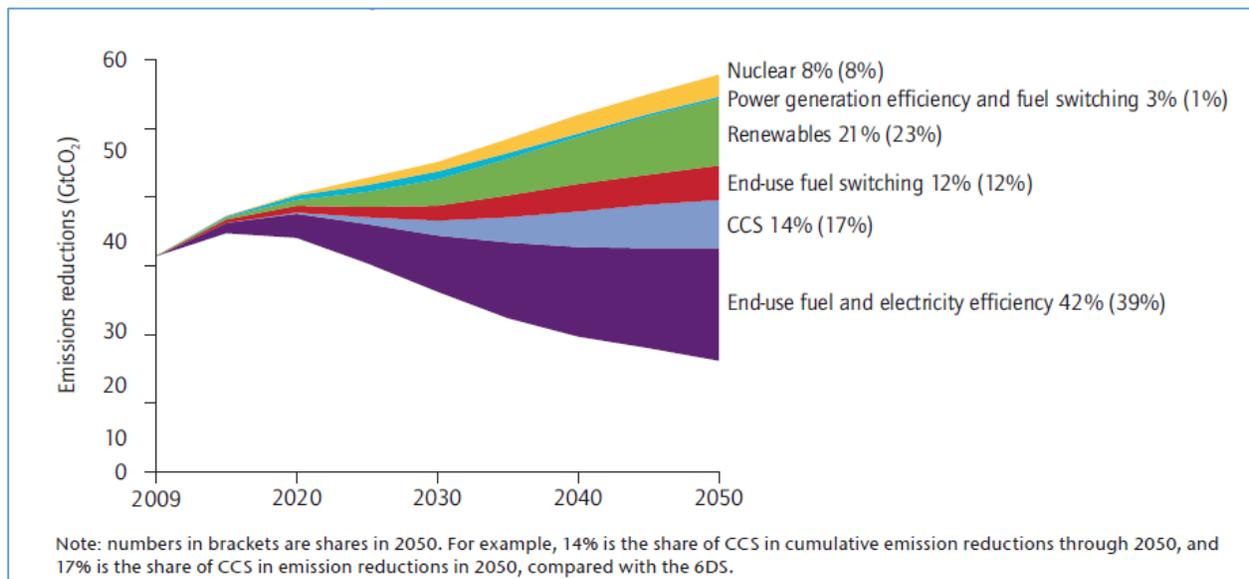
This report assesses the status of the current DOE program through a series of five chapters as follows:

- Chapter A: The CCS/CCUS Imperative
- Chapter B: Global Status of CCS/CCUS
- Chapter C: Overview of the Current DOE CCS/CCUS Programs
- Chapter D: CCS/CCUS Deployment Challenges
- Chapter E: Gap Analysis

Among the findings from each of these chapters.

Chapter A: The CCS/CCUS Imperative

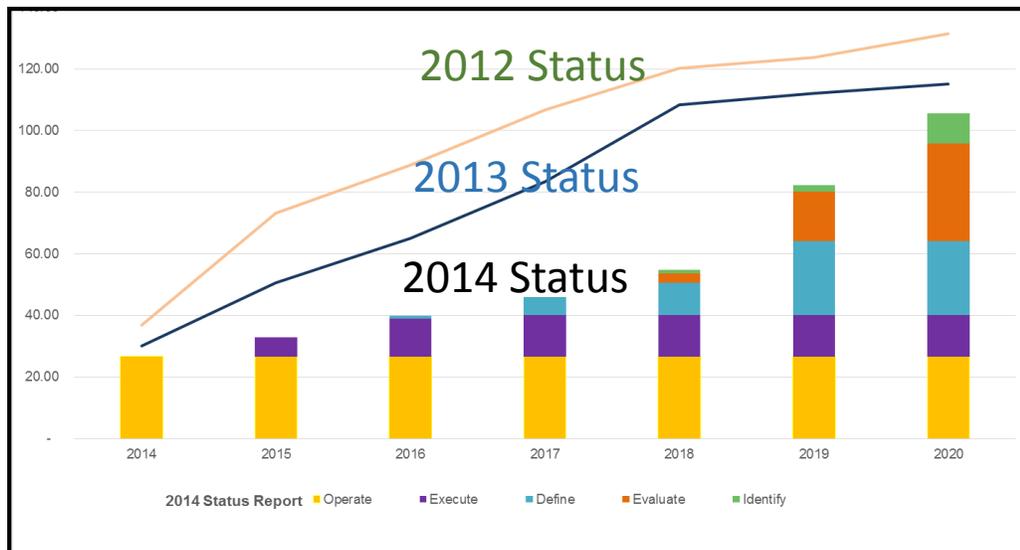
- CCS is the only large scale technology that can mitigate CO₂ emissions from fossil fuel use for electricity generation and key industrial sectors including cement production, iron and steel making, oil refining, and chemicals manufacturing.
- Not including CCS as a key mitigation technology is projected to increase the overall costs of meeting CO₂ emissions goals by 70% to 138%.
- U.S. CO₂ emissions represent less than 16% of world emissions. Thus, global and wide scale implementation of CCS is necessary to meet CO₂ emissions goals.
- DOE has taken on a leadership role in advancing CCS technology by supporting first mover CCS projects and fostering international collaborative efforts to deploy CCS, but this role must be strengthened if CCS is to be commercialized.



Chapter B: Global Status of CCS/CCUS

- Capital and operating costs for projects with CCS are more expensive than conventional technologies and carry greater technology and commercial risk. The bulk of the capital expenditure is associated with the addition of the capture plant and compression units, as well as the modifications to the power or industrial plant in the case of retrofits. Project risks include financing, permitting, public acceptance, cost overruns, schedule delays, performance, environmental compliance, operational flexibility, storage, and liability.
- Funding remains a major challenge. All large scale projects have a combination of public and private funding to help minimize risk exposure. Significant investments in time and resources are required even before reaching a final investment decision (e.g., storage site characterization for saline which can take 5-10 years). Projects generally include a basket of federal and state or provincial incentives (e.g., grants, tax credits, loan guarantees, etc.).
- Projects with CCS are more complex than conventional projects (from a project management, operations, and technical perspective), which can significantly impact overall project timelines and, thereby, increase costs. The regulatory approval process (especially associated with air and storage site permitting) is a key issue for many projects, which must typically factor in an additional 12-36 months into overall project timelines. Power plants or polygeneration facilities operating in competitive electricity markets must account for the additional time and complexity of negotiating power purchase agreements and other offtake contracts (e.g., CO₂, urea, etc.). Finally, many of these pioneer projects typically include a more rigorous investment due diligence process that is conducted during the front end engineering and design (FEED) study and final investment decision stages.
- The portfolio of large scale CCS projects is the result of public and private investments that were initiated 5-10 years ago and intended to advance technologies to the point of achieving commercial readiness. The CO₂ capture capacity of all projects in the operate, construction, and advanced planning stages (totalling nearly 65 million ton/year) is something less than the current CO₂ emissions from West Virginia’s coal fired power sector (77.6 million ton/year), which is multiples below the CCS levels called for by the IEA and other organizations.

CO2 Potentially Stored by Projects in the Pipeline



Chapter C: Overview of the Current DOE CCS/CCUS Programs

- Significantly more CCS/CCUS pilot and demonstration projects are needed in order to commercially deploy the technology.

Due to the high cost and high risk associated with power plant construction, demonstration projects are an absolute necessity. Without adequate demonstration, there can be no commercialization of CCS/CCUS. One or two demonstration units are not sufficient for “adequate demonstration”. Plant owners are looking for serial number 6, not serial number 2. That translates into a number of demonstration projects for several technologies. The penalties associated with the potential failure to meet cost and schedule estimates are too great for an individual plant owner to secure PUC rate base acceptance, permits, adequate funding, and insurance for a CCS/CCUS power plant project.

**DOE CCS Demonstration Projects
Portfolio of Capture and Storage Approaches**

	Plant Type		Sequestration			Feedstock
	Power	Industrial	Saline	EOR	Rate*	
Pre-combustion						
HECA (IGCC-Polygen)	X	X		X	2.55	NM Sub-bituminous Coal/Petrocoke Blend
Southern-Kemper Co. (IGCC)	X			X	3.0	MS Lignite
Summit Texas (IGCC-Polygen)	X	X		X	2.2	WY Sub-bituminous Coal
Leucadia, Lake Charles (Methanol & Hydrogen)		X		X	4.5	Petroleum Coke
Air Products and Chemicals, Inc. (SMR)		X		X	0.925	Natural Gas
ADM (Ethanol Production)		X	X		0.900	Corn Fermentation
Post-combustion						
NRG Energy	X			X	1.4	WY Sub-bituminous Coal
Oxy-combustion						
FutureGen 2.0	X		X		1.0	IL Bituminous /PRB Coal Blend

■ CCPI
 ■ ICCS Area 1
 ■ FutureGen 2.0
 *Rate in million metric tons per year



Active CCS/CCUS Demonstration Projects, DOE/NETL

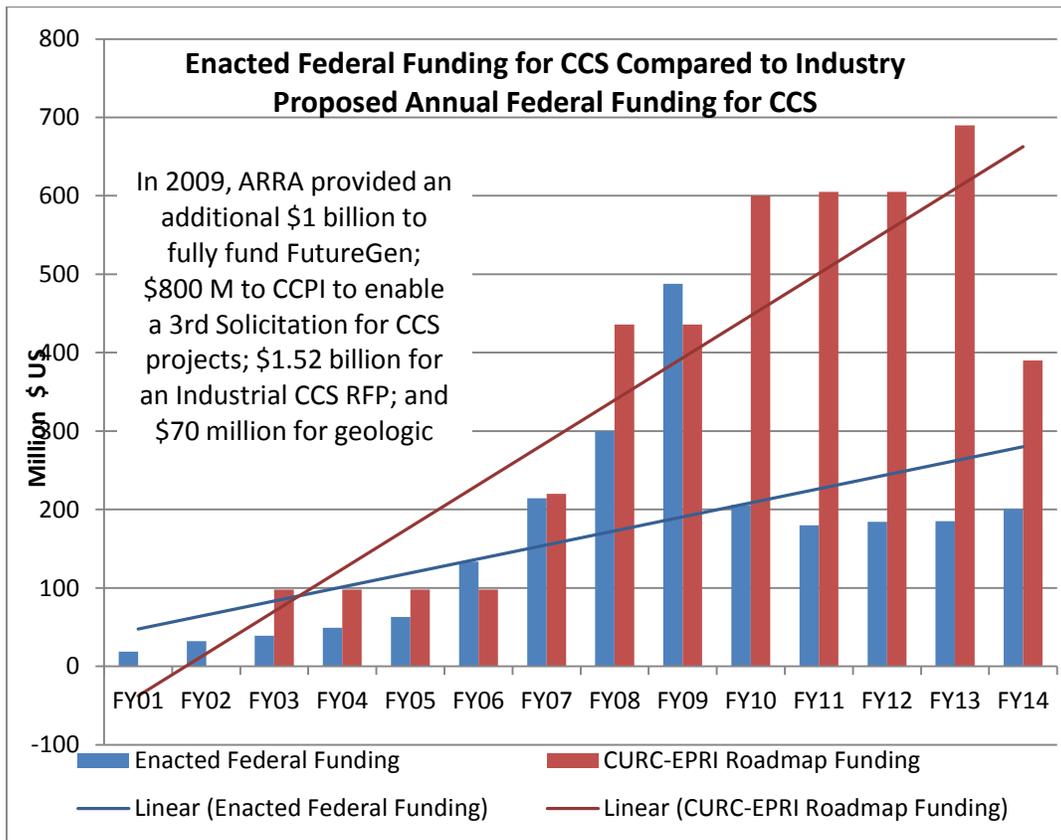
Note: Leucadia project has been cancelled.

- It is impossible to objectively assess progress against the DOE program goals. DOE has a world leading CCS RD&D portfolio. It has enabled the advancement of CCS technology to a point at which some newer CCS technologies are ready for pilot scale testing. Other technologies in the R&D pipeline hold promise for achieving significantly improved cost and environmental performance over the state of the art in the long term. However, the goals are presented in terms of the performance and cost of Nth-of-a-kind (NOAK) commercial systems, but the programs themselves consist of numerous relatively small projects in the early stages of development.

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- Funding for DOE programs is inconsistent with DOE goals.

The DOE programs have consistently been inadequately funded and, as a result, DOE incentive programs for deploying CCS are not as effective as they can and should be. In the absence of any near term market for CCS, significant federal financial support will be necessary for successful development, demonstration, and deployment of CCS. However, the level of federal funding provided to the CCS program is not sufficient to achieve the aggressive goals of the program. The current basket of incentives has not proven to be effective in getting a substantial number of demonstration projects to come to fruition. Without adequate demonstration, there can be no commercialization of CCS.



Federal Funding vs Industry Recommended Funding

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- CCS technology is not commercially available at large power plant scale.

The state of CCS development within DOE (no operating demos, two small demos/large pilots, and numerous R&D projects) establishes that CCS is not commercially available for large scale deployment at this time.

Program Area	Key Technology	Number of R&D Projects					Total
		TRL 1	TRL 2	TRL 3-4	TRL 5-6	TRL 7	
Post-Combustion Capture	<i>Solvents</i>		3	9	5	-	17
	<i>Sorbents</i>		3	9	2	-	14
	<i>Membranes</i>		4	5	1	-	10
	<i>Hybrid/Novel</i>		5	3	1	1	10
Pre-Combustion Capture	<i>Solvents</i>		2	1	1	→	3
	<i>Sorbents</i>		2	1	1	-	4
	<i>Membranes</i>		2	5	-	-	7
	<i>Hybrid/Novel</i>		3	-	-	-	3
Compression	<i>Compression</i>		-	-	2	-	2
TRL Totals			24	33	12	1	70
<p>Need for fresh, transformational ideas “Wave” of bench scale projects approaching graduation (1/2 of portfolio) Up to 12 candidate ≤1MW pilots progressing toward large pilot scale</p>							



Technology Readiness Levels (TRL) Levels of Carbon Capture R&D Portfolio, DOE/NETL

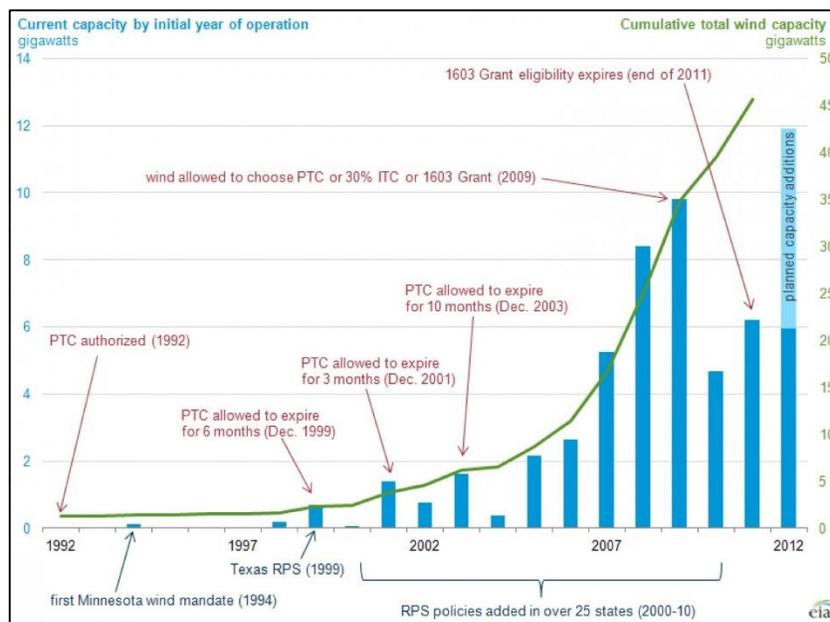
- Opportunities to exploit CO₂ for CO₂ EOR applications to expedite CCS/CCUS technology are hampered.

Projects that couple CO₂ EOR with CO₂ storage tend to have better economics and typically a higher chance for success than CCS projects with just storage. While the Weyburn-Midale CO₂ Monitoring and Storage Project has successfully demonstrated the possibility of safe storage and monitoring, verification, and accounting (MVA) to support a CO₂ EOR storage system, there are still unresolved regulatory issues in the U.S. associated with EOR storage that could impact project development.²

² <http://water.epa.gov/type/groundwater/uic/class6/upload/epa816p13004.pdf>

Chapter D: CCS/CCUS Deployment Challenges

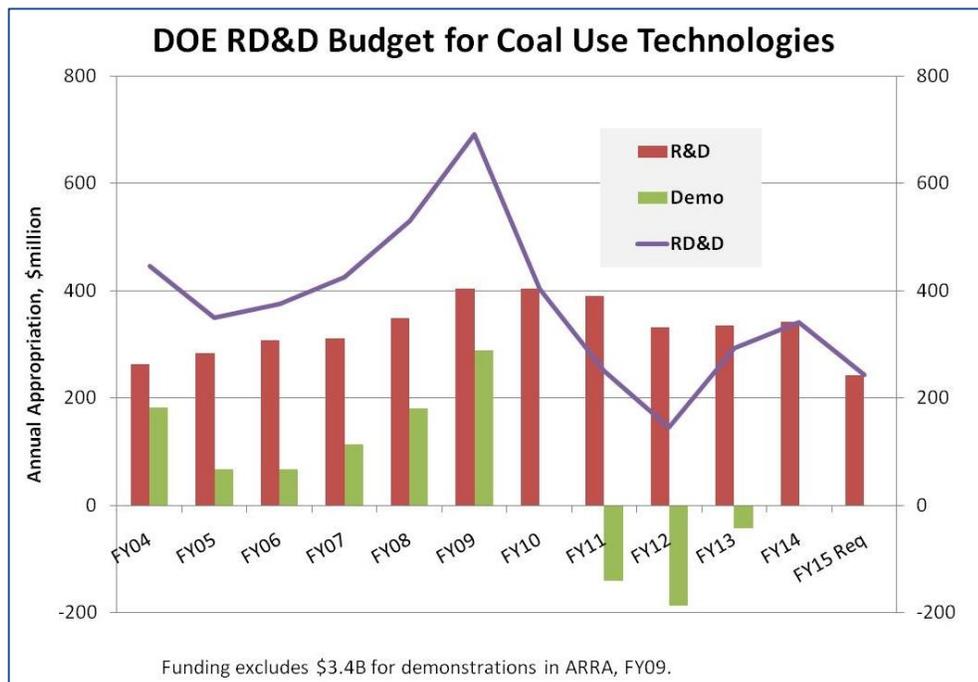
- The infrastructure for transportation and storage of massive quantities of captured CO₂ does not exist. Without this infrastructure, commercializing CCS/CCUS will be difficult.
- Financing power plants with CCS is a major issue. Power plant projects are large and costly. The means to monetize the entire CCS/CCUS process has not been identified.
- Legal and regulatory issues still remain unresolved. Currently proposed regulations have not been helpful in promoting CCS/CCUS. The confusion and uncertainty make the long process of planning, permitting, financing, constructing, and operating a plant that much more difficult.
- Public acceptance is still an issue. While there are some regions of the U.S. that might accept a CCS project, many others will not. There is a parallel public perception association between fracking and CCS that should be more closely observed. Some regions have banned fracking. They might also ban injection and storage of CO₂.
- First generation technologies are costly. Second generation technologies offer some potential, but are still at the early stages of development. Continued R&D at all stages is needed to help reduce costs.
- General Equilibrium Models can be helpful as tools to provide guidance, but should be used with caution as neither the economy nor the climate are truly at equilibrium.
- CO₂ utilization can improve the economics of early adopter plants. However, the magnitude of the amount of CO₂ that must be captured to meet CO₂ emission reduction goals is much greater than the potential economic uses. For the most part, utilization is able to handle millions of tons, leading to perhaps some modest total of billions of tons. Reduction requirements will be in the thousands of billions of tons.
- There is a policy mismatch between CCS/CCUS technology funding and other DOE energy programs. Policy parity would provide more energy options for the U.S.



Potential Benefit from Policy Parity ~ Wind Energy Industry Example

Chapter E: Gap Analysis

- The current DOE CCS/CCUS program does not include any budget or plan to fund demonstrations of 2nd generation CO₂ capture technologies. Such demonstrations need to be operating in the 2020-2025 timeframe in order to foster widespread deployment of CCUS on power plants in the 2030s. For demonstrations to begin operating in the 2020-2025 timeframe, financial commitments need to be made in near future (2015-16).
- At the same time, DOE needs to continue to “feed the pipeline” by sponsoring early stage R&D on transformational technologies for CO₂ capture as well as technologies which can improve the efficiency of CO₂ compression.
- While the DOE should be justifiably proud of its CO₂ storage program, in its current form it will not be sufficient to reach the desired endpoint. DOE’s goal should be to have 5-10 GW of CCUS projects operating by 2025. In addition, DOE’s program needs to address the risk a CCUS project developer faces of not finding a suitable site for CO₂ storage in a timely and economic fashion. This can be addressed by carrying out a program to identify and certify at least one reservoir which is capable of storing a minimum of 100 million tons of CO₂ at a cost of less than \$10/ton in each of the seven regions covered by DOE’s Regional Carbon Sequestration Partnership (RCSP) program.
- Control of greenhouse gas emissions is a global problem in need of global solutions. DOE has undertaken important steps to form international collaborations, but more will be needed.
- In the past several years, no federal funding has been made available for commercial scale demonstrations of CCS/CCUS technology. The existing DOE loan guarantee program for CCS/CCUS projects will not be sufficient to move these projects forward. There is a need to find creative mechanisms to finance CCS/CCUS projects.



Principal Theme & Consideration

The basic theme of this report is that while the DOE is indisputably a world leader in the development of CCS technology, the DOE CCS/CCUS program has not yet achieved critical mass. While there have been some successes, there is a need for a substantial increase in the number of large scale demonstration projects for both capture and storage technologies before either system even approaches commercialization. The current number of demonstration projects that are in operation or under construction globally is 22. The projected need by 2050 is 3400. The current global CO₂ storage rate is 40 million tons/year. The projected need is 10 billion tons/year. There are not enough demonstration projects to meet the need. Without adequate demonstration, there can be no commercialization. This fact applies to all aspects of CCS, including capture, transportation, utilization, and storage. There is no point in capturing CO₂ if there is no place to use it or store it.

The key considerations supporting this analysis are as follows:

- In order to achieve CCS deployment at commercial scale, policy parity for CCS with other low carbon technologies and options is required.
- Technology and funding incentives must be significantly better coordinated to be effective.
- DOE program goals need far greater clarity and alignment with commercial technology and funding approaches used by industry.
- Funding for CCS RD&D is limited and must be enhanced and focused.
- Public acceptance continues to be a major hurdle.
- Control of CO₂ emissions is an international issue in need of international Initiatives.

Key Recommendations

In order to achieve CCS deployment at commercial scale, policy parity for CCS with other low carbon technologies and options is required.

- Policy parity for CCS in funding, extending tax credits and other subsidies provided to renewable energy sources, will facilitate creation of a robust CCS industry in the U.S., benefiting the American people and leading to the development of the lowest cost, near zero emission energy technology. Such technology would be available for electric generation as well as all fossil fuel dependent industrial applications. The NCC recommends that DOE take a stronger position on the need for policy parity with respect to funding allocations.

Technology and funding incentives must be significantly better coordinated to be effective.

- The NCC recommends that DOE develop a plan to have a total of 5–10 GW of CCS/CCUS demonstration projects in operation in the U.S. by 2025.
- The NCC recommends that all federal incentives provided by the DOE and other federal agencies for CCS demonstration projects undergo a coordinated review for their combined adequacy and effectiveness in supporting CCS deployment. If necessary, combinations of incentives or new incentives could be utilized to achieve the desired level of demonstration projects. Examples of such incentives include feed in tariffs, tax credits, production credits, loan guarantees, and “contracts for differences”. This coordinated review needs to be completed in time to achieve the installation of 5–10 GW of CCS demonstration projects by 2025.
- The NCC recommends that DOE expand its Regional Carbon Sequestration Partnership (RCSP) program to identify and certify at least one reservoir in each region that is capable of storing a minimum of 100 million tons of CO₂ at a cost of less than \$10/ton by 2025.

DOE program goals need far greater clarity and alignment with commercial technology and financing approaches used by industry.

- The NCC recommends that DOE and industry convene a task force to clearly define the role and objectives of individual projects in achieving broad program goals. The aim is to better understand industry technology goals and needs and to understand industry criteria for investment in CCS technologies throughout the entire development pipeline. Prioritization of projects is critical to achieving overall goals with limited budgets, consistent with the need to bring CCS technologies up to Technology Readiness Level 9 (TRL-9).

Funding for CCS RD&D is limited and must be enhanced and focused.

- The NCC recommends that DOE continue its strategy of fostering a portfolio of technologies for implementing CCS. It is important to maintain DOE’s approach of “priming the pump” with early stage funding for promising concepts, but in recognition of budgetary constraints and the need to move more quickly in getting larger scale CCS projects operating, the NCC recommends that after technologies reach TRL 4, DOE cull its support to only those technologies which show a clear promise of meeting or exceeding DOE’s CCS performance goals.
- The NCC recommends that DOE develop a plan for demonstrating second generation and transformational CCS technologies at a scale of 25–50 MW by 2020 and make subsequent budget requests to Congress to carry out the plan. However, these demonstrations should only move forward for technologies which have a clear advantage in cost and performance compared to first generation CCS technologies.

Public acceptance continues to be a major hurdle.

- The NCC recommends that DOE accelerate its current efforts in CCS/CCUS public engagement, education, and training activities. Outreach efforts should target counties and states with demonstration projects and regions that have potential infrastructure developments (e.g., CO₂ pipelines and storage sites). Training activity should build workforce capacity across the CCS/CCUS chain and build U.S. leadership and knowhow to meet potential national and international demand.

Control of GHG emissions is an international issue in need of international initiatives.

- The NCC recommends that DOE maintain its existing CCS/CCUS international collaboration efforts including the Carbon Sequestration Leadership Forum (CSLF) and the U.S.-China Clean Energy Research Center (CERC).
- International partnerships in commerce should also be pursued. The NCC recommends that the DOE explore ways to foster CCS/CCUS demonstrations in developing nations which are rapidly increasing their CO₂ emissions, such as China and India. In particular, conducting CO₂ utilization and storage projects using CO₂ from new and existing coal gasification projects in these countries, could be a low cost means to increase global knowledge and acceptance of commercial scale CO₂ storage.



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, 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, industrial, manufacturing and energy needs. Our nation’s primary energy challenge is to find a way to balance our social, economic and environmental objectives.

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 its 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.

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